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[Title of the Invention]

ADJUSTING DEVICE FOR SHAKE CORRECTION CAMERA,  
10 SHAKE CORRECTION CAMERA AND METHOD OF ADJUSTING SHAKE  
CORRECTION CAMERA

[Abstract]

[Object]

15 Displacement in the detection direction of angular  
velocity detecting unit is adjusted in the final  
assembly state of the camera.

[Constitution]

An adjusting device for a shake correction camera  
20 is a device for adjusting a shake correction function  
of the shake correction camera and includes: an  
information transferring unit for transferring  
information to and from the shake correction camera; a  
shake applying unit for applying a sinusoidal vibration  
25 with a predetermined angular velocity amplitude in the  
first and the second direction of the shake correction  
camera; a first calculating unit for calculating a

first and a second angle displacement amount between  
the first and the second direction and the directions  
in which the first and the second angular velocity  
detecting unit detect the angular velocity based on the  
5 output values of the first and second angular velocity  
detecting units of the shake correction camera produced  
when the sinusoidal vibration is applied in the first  
and the second direction of the shake correction  
camera; a second calculating unit for calculating a  
10 first and a second angle displacement adjustment value  
based on the first and the second angle displacement  
amount; and a writing unit for writing the first and  
the second angle displacement adjustment value in the  
storing unit of the shake correction camera.

15

[Claims for the Patent]

[Claim 1]

An adjusting device for adjusting the shake correction function of a shake correction camera

5 including:

an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to  
10 correct a shake caused by vibration;

a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction;

15 a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction;

a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for  
20 adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular

velocity;

a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of said first angular velocity

5 detecting unit by said first angle displacement adjustment value stored in said storing unit and the output of said second angular velocity detecting unit; and

a second angle displacement correcting unit for  
10 correcting an error due to the second angle displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value stored in said storing unit and the output of said first angular velocity  
15 detecting unit; the adjusting device characterized by comprising:

an information transferring unit for transferring information to and from the shake correction camera;

a shake applying unit for applying a sinusoidal  
20 vibration with a predetermined angular velocity amplitude in the first and the second direction of the shake correction camera;

a first calculating unit for calculating a first angle displacement amount between the first direction  
25 and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second

direction and the direction in which said second angular velocity detecting unit detects the angular velocity based on the output values of said first and second angular velocity detecting units produced when  
5 the sinusoidal vibration is applied to the shake correction camera;

a second calculating unit for calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the  
10 direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second  
15 angular velocity detecting unit detects the angular velocity based on the first and the second angle displacement amount calculated by said first calculating unit; and

a writing unit for writing the first and the  
20 second angle displacement adjustment value calculated by said second calculating unit in said storing unit of the shake correction camera.

[Claim 2]

The adjusting device for a shake correction camera  
25 according to claim 1, characterized in that

said first calculating unit calculates the first and the second angle displacement amount based on the

maximum and the minimum value of each of the output values of said first and second angular velocity detecting units.

[Claim 3]

5           An adjusting device for adjusting the shake correction function of a shake correction camera including:

          an optical axis varying unit for varying the optical axis of a photographic optical system in a  
10   first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration;

          a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the  
15   direction substantially coinciding with the first direction;

          a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second  
20   direction;

          a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity  
25   detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second

direction and the direction in which said second angular velocity detecting unit detects the angular velocity;

5 a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of said first angular velocity detecting unit by the first angle displacement adjustment value stored in said storing unit and the output of said second angular velocity detecting unit;

10 and

a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value stored in said storing unit and the output of said first angular velocity detecting unit; the adjusting device characterized by comprising:

15

an information transferring unit for transferring information to and from the shake correction camera;

20

a shake applying unit for applying a sinusoidal vibration with a predetermined angular amplitude in the first and the second direction of the shake correction camera;

25 a first calculating unit for calculating a first angle displacement amount between the first direction and the direction in which said first angular velocity

detecting unit detects the angular velocity and a second angle displacement amount between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity based on a first and a second calculated value in which a first output value of said first angular velocity detecting unit and a second output value of said second angular velocity detecting unit produced when the sinusoidal vibration is applied in the first direction of the shake correction camera are integrated or accumulated and a third and a fourth calculated value in which a third output value of said first angular velocity detecting unit and a fourth output value of said second angular velocity detecting unit produced when the sinusoidal vibration is applied in the second direction are integrated or accumulated;

a second calculating unit for calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity based on the first and the second angle displacement amount calculated by said first



calculating unit respectively; and

        a writing unit for writing the first and the  
second angle displacement adjustment value calculated  
by said second calculating unit in said storing unit of  
5 the shake correction camera.

[Claim 4]

        The adjusting device for a shake correction camera  
according to claim 3, characterized in that

        said first calculating unit calculates the first  
10 and the second angle displacement amount based on the  
maximum and the minimum value of each of the first, the  
second, the third and the fourth calculated value.

[Claim 5]

        A shake correction camera including:

15       an optical axis varying unit for varying the  
optical axis of a photographic optical system in a  
first and a second direction substantially  
perpendicular to the direction of the optical axis to  
correct a shake caused by vibration;

20       a first angular velocity detecting unit for  
detecting an angular velocity caused by a shake in the  
direction substantially coinciding with the first  
direction;

        a second angular velocity detecting unit for  
25 detecting an angular velocity caused by a shake in the  
direction substantially coinciding with the second  
direction;

a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity

5 detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular

10 velocity;

a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of said first angular velocity detecting unit by the first angle displacement

15 adjustment value stored in said storing unit and the output of said second angular velocity detecting unit; and

a second angle displacement correcting unit for correcting an error due to the second angle

20 displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value stored in said storing unit and the output of said first angular velocity detecting unit; the shake correction camera

25 characterized in that a first angle displacement amount between the first direction and the direction in which said first angular velocity detecting unit detects the

angular velocity and a second angle displacement amount between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity are calculated based on a first output value of said first angular velocity detecting unit and a second output value of said second angular velocity detecting unit produced when a first sinusoidal vibration with a predetermined angular velocity amplitude is applied in the first direction of the shake correction camera and a third output value of said first angular velocity detecting unit and a fourth output value of said second angular velocity detecting unit produced when a second sinusoidal vibration with a predetermined angular velocity amplitude is applied in the second direction of the shake correction camera and the first and the second angle displacement adjustment value are calculated based on the first and the second angle displacement amount respectively.

[Claim 6]

The shake correction camera according to claim 5, characterized in that the first and the second angle displacement amount are calculated based on the maximum and the minimum value of each of the first, the second, the third and the fourth output value.

[Claim 7]

A shake correction camera including:

an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to  
5 correct a shake caused by vibration;

a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction;

10 a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction;

a storing unit for storing a first angle  
15 displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a  
20 second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity;

a first angle displacement correcting unit for  
25 correcting an error due to the first angle displacement amount of output of said first angular velocity detecting unit by the first angle displacement

adjustment value stored in said storing unit and the output of said second angular velocity detecting unit; and

5 a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value stored in said storing unit and the output of said first angular velocity  
10 detecting unit; the shake correction camera characterized in that a first angle displacement amount between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement amount  
15 between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity are calculated based on a first and a second calculated value in which a first output value of said first angular velocity detecting unit and a  
20 second output value of said second angular velocity detecting unit produced when a first sinusoidal vibration with a predetermined angular amplitude is applied in the first direction of the shake correction camera are integrated or accumulated and a third and a  
25 fourth calculated value in which a third output value of said first angular velocity detecting unit and a fourth output value of said second angular velocity

detecting unit produced when a second sinusoidal vibration with a predetermined angular amplitude is applied in the second direction of the shake correction camera are integrated or accumulated and the first and  
5 the second angle displacement adjustment value are calculated based on the first and the second angle displacement amount calculated by said first calculation unit.

[Claim 8]

10 The shake correction camera according to claim 7, characterized in that

the first and the second angle displacement amount are calculated based on the maximum and the minimum value of each of the first, the second, the third and  
15 the fourth calculated value.

[Claim 9]

A method of adjusting the shake correction function of a shake correction camera including:

an optical axis varying unit for varying the  
20 optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; and

a first and a second shake detecting unit for  
25 detecting an angular velocity caused by a shake in the directions substantially coinciding with the first and the second direction respectively; the method

characterized by comprising the steps of:

applying a sinusoidal vibration with a  
predetermined angular velocity amplitude in the first  
and the second direction of the shake correction

5 camera;

calculating a first angle displacement adjustment  
value for adjusting an angle displacement between the  
first direction and the direction in which said first  
angular velocity detecting unit detects the angular  
10 velocity and a second angle displacement adjustment  
value for adjusting an angle displacement between the  
second direction and the direction in which said second  
angular velocity detecting unit detects the angular  
velocity based on the output values of said first and  
15 second angular velocity detecting units of the shake  
correction camera or the maximum and the minimum value  
thereof at that point; and

correcting an error due to the first angle  
displacement amount of output of said first angular  
20 velocity detecting unit by the first angle displacement  
adjustment value and the output of said second angular  
velocity detecting unit and an error due to the second  
angle displacement amount of output of said second  
angular velocity detecting unit by the second angle  
25 displacement adjustment value and the output of said  
first angular velocity detecting unit.

[Claim 10]

A method of adjusting the shake correction function of a shake correction camera including:

an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; and

a first and a second shake detecting unit for detecting an angular velocity caused by a shake in the directions substantially coinciding with the first and the second direction respectively; the method characterized by comprising the steps of:

applying a sinusoidal vibration with a predetermined angular amplitude in the first and the second direction of the shake correction camera;

calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity based on the integrated or the accumulated values of the output values of said first and second angular velocity detecting units of the shake correction camera or the maximum and the minimum value



thereof at that point; and

correcting an error due to the first angle displacement amount of output of said first angular velocity detecting unit by the first angle displacement  
5 adjustment value and the output of said second angular velocity detecting unit and an error due to the second angle displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value and the output of said  
10 first angular velocity detecting unit.

[Detailed Description of the Invention]

[0001]

[Industrial Application Field]

15 The present invention relates to an adjusting device for a shake correction camera capable of correcting image shake due to hand shake produced at the time of taking a picture, the shake correction camera and a method of adjusting the shake correction  
20 camera.

[0002]

[Conventional Art]

As a conventional shake correction camera of this type, there has been known the following shake  
25 correction camera. An angular velocity detecting circuit using an angular velocity sensor detects an angular velocity due to shake in two directions on a

vertical plane at least perpendicular to the optical axis of a camera. The optical axis of a photographing optical system is moved by shifting a shake correcting lens (or, a vibration-proof lens) being part of a photographing lens in substantially the same direction as the detection direction according to the detected angular velocity. The photographing optical system is driven in such a manner that the rotation of an actuator such as a motor is reduced by a gear and the rotational motion is converted to a linear motion. Thereby, image shake due to shake generated in a camera is corrected (this control is referred to also as vibration-proof control).

[0003]

Such a camera is separated into some portions (sub-assembly parts) in a production stage and produced. The operation of each sub-assembly part is inspected and then a final assembly is performed. For example, a correction lens shifting mechanism for shifting a correction lens by rotating a motor is inspected as to whether it is normally operated as one assembly part and then it is assembled into a camera body. The angular velocity detecting circuit for detecting an angular velocity due to hand shake is similar to the above.

[0004]

[Problems to be Solved by the Invention]

The above conventional shake correction camera has the following problems. Firstly, even if a correction lens shifting mechanism or an angular velocity detecting circuit are non-defective at the time of inspecting its operation at a sub-assembly parts stage, the operation can be defective at a stage where they are assembled into a camera body or good operative performances cannot be obtained. In the final assembly state of the camera, the correction lens shifting mechanism and/or the angular velocity detecting circuit cannot be inspected.

[0005]

Secondly, the output of an angular velocity sensor used in an angular velocity detecting circuit has an individual difference (dispersion between apparatus). The output value of each angular velocity sensor is not constant when a predetermined angular velocity is applied to the angular velocity sensors. An amplifier for an angular velocity detecting circuit disperses in amplification factor. In most cases, the output value of the angular velocity detecting circuit is converted to a digital value by an A/D converter incorporated in a microcomputer. The A/D converter has also an individual difference and a digital value A/D converted from a predetermined input voltage is not constant. It is not so much difficult to adjust dispersion in the gain of the angular velocity detecting circuit in a

sub-assembly state, however, there is still left an error caused by dispersion in the A/D converter. In the case where shake is corrected with such a gain dispersed, a problem is caused in that a shake correction is not accurately performed.

[0006]

Thirdly, the angular velocity sensor used in the angular velocity detecting circuit is supported in space by an oscillator-wire shaped supporting member for determining the direction of an axis detecting the angular velocity of rotational motion, as disclosed in, for example, Japanese Patent Laid-Open No. 2-228518. In the case where the angular velocity sensor in which the legs of the supporting member are fixed, it is prone to cause an individual difference of a detecting axis in terms of structure. Furthermore, there is produced an error in the attachment direction at a stage where the angular velocity sensor is attached to the angular velocity detecting circuit and the angular velocity detecting circuit is incorporated into the camera body. Those cause displacement between the direction in which the angular velocity detecting circuit detects an angular velocity and the direction the shake correction lens is actually shifted to move the optical axis (the displacement is also referred to as detection angle displacement, because the displacement is dominant in the direction detected by

the angular velocity detecting circuit). The detection angle displacement can be 5° or more. Thus, there is a problem in that the detection angle displacement between the angular velocity detecting direction and the optical axis moving direction cannot accurately perform a shake correction.

[0007]

The present invention has been made to solve the above problems and for its object to perform an accurate shake correction by inspecting the operation of each sub-assembly part for the shake correction lens shifting mechanism and the angular velocity detecting circuit and adjusting the dispersion in the gain of the output value between apparatus of each sub-assembly part.

[0008]

[Means for Solving the Problems]

To achieve the above object, according to a first solution aspect of the present invention, in an adjusting device for adjusting the shake correction function of a shake correction camera including: an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; a first angular velocity detecting unit for detecting an angular velocity caused by a shake in

the direction substantially coinciding with the first direction; a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second  
5 direction; a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle  
10 displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity; a first angle displacement correcting unit for correcting an  
15 error due to the first angle displacement amount of output of the first angular velocity detecting unit by the first angle displacement adjustment value stored in the storing unit and the output of the second angular velocity detecting unit; and a second angle  
20 displacement correcting unit for correcting an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the second angle displacement adjustment value stored in the storing unit and the output of the first angular  
25 velocity detecting unit; the adjusting device is characterized by including: an information transferring unit for transferring information to and from the shake

correction camera; a shake applying unit for applying a sinusoidal vibration with a predetermined angular velocity amplitude in the first and the second direction of the shake correction camera; a first  
5 calculating unit for calculating a first angle displacement amount between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second direction and  
10 the direction in which the second angular velocity detecting unit detects the angular velocity based on the output values of the first and second angular velocity detecting units produced when the sinusoidal vibration is applied to the shake correction camera;  
15 and a second calculating unit for calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle  
20 displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on the first and the second angle displacement amount  
25 calculated by the first calculating unit; and a writing unit for writing the first and the second angle displacement adjustment value calculated by the second

calculating unit in the storing unit of the shake correction camera.

[0009]

A second solution aspect according to the first  
5 solution aspect of the present invention is characterized in that the first calculating unit calculates the first and the second angle displacement amount based on the maximum and the minimum value of each of the output values of the first and second  
10 angular velocity detecting units.

[0010]

According to a third solution aspect of the present invention, in an adjusting device for adjusting the shake correction function of a shake correction  
15 camera including: an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; a first angular  
20 velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction; a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction  
25 substantially coinciding with the second direction; a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement



between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement

5 between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity; a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of the first angular

10 velocity detecting unit by the first angle displacement adjustment value stored in the storing unit and the output of the second angular velocity detecting unit; and a second angle displacement correcting unit for correcting an error due to the second angle

15 displacement amount of output of the second angular velocity detecting unit by the second angle displacement adjustment value stored in the storing unit and the output of the first angular velocity detecting unit; the adjusting device is characterized

20 by including: an information transferring unit for transferring information to and from the shake correction camera; a shake applying unit for applying a sinusoidal vibration with a predetermined angular amplitude in the first and the second direction of the

25 shake correction camera; a first calculating unit for calculating a first angle displacement amount between the first direction and the direction in which the

first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on a first and a second calculated value in which a first output value of the first angular velocity detecting unit and a second output value of the second angular velocity detecting unit produced when the sinusoidal vibration is applied in the first direction of the shake correction camera are integrated or accumulated and a third and a fourth calculated value in which a third output value of the first angular velocity detecting unit and a fourth output value of the second angular velocity detecting unit produced when the sinusoidal vibration is applied in the second direction are integrated or accumulated; a second calculating unit for calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on the first and the second angle displacement amount calculated by the first calculating unit respectively;

and a writing unit for writing the first and the second angle displacement adjustment value calculated by the second calculating unit in the storing unit of the shake correction camera.

5 [0011]

A fourth solution aspect according to the third solution aspect of the present invention is characterized in that the first calculating unit calculates the first and the second angle displacement amount based on the maximum and the minimum value of each of the first, the second, the third and the fourth calculated value.

[0012]

According to a first solution aspect of a shake correction camera of the present invention, in the shake correction camera including: an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction; a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction; a storing unit for storing a first angle

displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity; a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of the first angular velocity detecting unit by the first angle displacement adjustment value stored in the storing unit and the output of the second angular velocity detecting unit; and a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the second angle displacement adjustment value stored in the storing unit and the output of the first angular velocity detecting unit; the shake correction camera is characterized in that a first angle displacement amount between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity are calculated based on a first output

value of the first angular velocity detecting unit and a second output value of the second angular velocity detecting unit produced when a first sinusoidal vibration with a predetermined angular velocity amplitude is applied in the first direction of the shake correction camera and a third output value of the first angular velocity detecting unit and a fourth output value of the second angular velocity detecting unit produced when a second sinusoidal vibration with a predetermined angular velocity amplitude is applied in the second direction of the shake correction camera and the first and the second angle displacement adjustment value are calculated based on the first and the second angle displacement amount respectively.

[0013]

A second solution aspect according to the first solution aspect of the shake correction camera of the present invention is characterized in that the first and the second angle displacement amount are calculated based on the maximum and the minimum value of each of the first, the second, the third and the fourth output value.

[0014]

According to a third solution aspect of a shake correction camera of the present invention, in the shake correction camera including: an optical axis varying unit for varying the optical axis of a

photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; a first angular velocity detecting unit for  
5 detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction; a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second  
10 direction; a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle  
15 displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity; a first angle displacement correcting unit for correcting an  
20 error due to the first angle displacement amount of output of the first angular velocity detecting unit by the first angle displacement adjustment value stored in the storing unit and the output of the second angular velocity detecting unit; and a second angle  
25 displacement correcting unit for correcting an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the

second angle displacement adjustment value stored in the storing unit and the output of the first angular velocity detecting unit; the shake correction camera is characterized in that a first angle displacement amount  
5 between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second direction and the direction in which the second angular velocity detecting unit detects the  
10 angular velocity are calculated based on a first and a second calculated value in which a first output value of the first angular velocity detecting unit and a second output value of the second angular velocity detecting unit produced when a first sinusoidal  
15 vibration with a predetermined angular amplitude is applied in the first direction of the shake correction camera are integrated or accumulated and a third and a fourth calculated value in which a third output value of the first angular velocity detecting unit and a  
20 fourth output value of the second angular velocity detecting unit produced when a second sinusoidal vibration with a predetermined angular amplitude is applied in the second direction of the shake correction camera are integrated or accumulated and the first and  
25 the second angle displacement adjustment value are calculated based on the first and the second angle displacement amount calculated by the first calculation

unit.

[0015]

A fourth solution aspect according to the third solution aspect of the shake correction camera of the present invention is characterized in that the first and the second angle displacement amount are calculated based on the maximum and the minimum value of each of the first, the second, the third and the fourth calculated value.

10 [0016]

According to a first solution aspect of a method of adjusting the shake correction function of a shake correction camera of the present invention, in a method of adjusting the shake correction function of the shake correction camera including: an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; and a first and a second shake detecting unit for detecting an angular velocity caused by a shake in the directions substantially coinciding with the first and the second direction respectively; the method is characterized by including the steps of: applying a sinusoidal vibration with a predetermined angular velocity amplitude in the first and the second direction of the shake correction camera; calculating a



first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a  
5 second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on the output values of the first and second  
10 angular velocity detecting units of the shake correction camera or the maximum and the minimum value thereof at that point; and correcting an error due to the first angle displacement amount of output of the first angular velocity detecting unit by the first  
15 angle displacement adjustment value and the output of the second angular velocity detecting unit and an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the second angle displacement adjustment value and the  
20 output of the first angular velocity detecting unit.  
[0017]

According to a second solution aspect of a method of adjusting the shake correction function of a shake correction camera of the present invention, in a method  
25 of adjusting the shake correction function of the shake correction camera including: an optical axis varying unit for varying the optical axis of a photographic

optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; and a first and a second shake detecting unit for

5 detecting an angular velocity caused by a shake in the directions substantially coinciding with the first and the second direction respectively; the method is characterized by including the steps of: applying a sinusoidal vibration with a predetermined angular

10 amplitude in the first and the second direction of the shake correction camera; calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting

15 unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on

20 the integrated or the accumulated values of the output values of the first and second angular velocity detecting units of the shake correction camera or the maximum and the minimum value thereof at that point; and correcting an error due to the first angle

25 displacement amount of output of the first angular velocity detecting unit by the first angle displacement adjustment value and the output of the second angular

velocity detecting unit and an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the second angle displacement adjustment value and the output of the first angular velocity detecting unit.

[0018]

[Operation]

According to the solution aspect of the present invention, a sinusoidal oscillation is applied to a first and a second direction being the direction in which the optical axis of a photographing optical system of the shake correction camera is varied and the first and the second amount of angle displacement is calculated between the first and the second direction and the angular velocity detecting direction by the first and the second angular velocity detecting unit based on the output values of the first and the second angular velocity detecting unit. In addition, the first and the second angle displacement adjustment value are calculated from the first and the second amount of angle displacement and stored in a storing unit. The output error of the first and the second angular velocity detecting unit is corrected based on the first and the second angle displacement adjustment value stored in the storing unit. Accordingly, an attachment error of the first and the second angular velocity detecting unit produced at the time of

assembling the camera does not influence the accuracy of shake correction.

[0019]

[Embodiments]

5           One embodiment of the present invention is described below with reference to the drawings. Figure 1 is a schematic diagram illustrating the configuration of portions of a camera, a communication tool and a shaking table. First, the portion on a camera side is  
10 described. The camera of the present embodiment is formed of photographic optical systems 11 to 14, a CPU 1, X and Y axis lens position detecting circuits 6 and 7 electrically connected to the CPU 1, X and Y axis motor driving circuits 2 and 3 and yaw and pitch  
15 angular velocity detecting circuits 8 and 9. The photographic optical systems 11 to 14 include four photographic lenses 11, 12, 13 and 14. The photographic lens 13 functions as a lens correcting image shake due to hand shake (hereinafter, referred to  
20 as a "vibration-proof lens 13"). The yaw and the pitch angular velocity detecting circuit 8 and 9 detect angular velocity due to hand shake in the yaw and the pitch direction in two axes (X and Y axes) direction on a plane surface orthogonal to a photographing optical  
25 axis. The CPU 1 is a one-chip microcomputer for controlling the sequence of the camera and has the calculation function of performing various calculations,

the clock timer function of measuring time, the timer interruption process of performing the process at a constant time interval, the PWM output function of outputting any duty, the function of A/D converting the output of the yaw and the pitch angular velocity detecting circuit 8 and 9, the communication function with the communication-tool side and the shutter function of performing an exposure process. The X and the Y axis motor driving circuit 2 and 3 drive the X and the Y axis motor 4 and 5 respectively to move the vibration-proof lens 13 in the X and the Y axis direction. The X and the Y axis lens position detecting circuit 6 and 7 detect positions in the X and the Y axis direction of the vibration-proof lens 13.

15 [0020]

The CPU 1 is electrically connected to an E2PROM 10, a half-depression SW 16, and a full-depression SW 17. The E2PROM 10 is a non-volatile memory and stores a gain adjustment value for correcting dispersion in the gain of the yaw and the pitch angular velocity detecting circuit 8 and 9 and a detection-angle displacement adjustment value for correcting detection direction displacement of angular velocity of the yaw and the pitch angular velocity detecting circuit 8 and 9. The half-depression SW 16 is a switch which is turned on by half depressing a release button and the full-depression SW 17 is a switch which is turned on by

fully depressing the release button.

[0021]

The operation of the camera is described below.

The yaw and the pitch angular velocity detecting

5 circuit 8 and 9 detect an angular velocity caused by a hand shake of the camera. The output values of the circuits are transmitted to the CPU 1. The CPU 1 A/D converts the output values to digital signals and detects the angular velocity of the hand shake. The

10 CPU 1 performs a predetermined calculation based on the angular velocity, the gain adjustment value and the detection-angle displacement adjustment value stored in the E2PROM 10 to calculate an appropriate driving amount of the vibration-proof lens 13. The CPU 1

15 causes the X and the Y axis motor driving circuit 2 and 3 to drive the X and the Y axis motor 4 and 5 respectively. The rotary driving force of the X and the Y axis motor 4 and 5 is converted to a linear motion by, for example, a gear train to move the

20 vibration-proof lens 13 at an appropriate velocity in the X and the Y axis direction so that a hand shake on the image surface is cancelled. The move of the vibration-proof lens 13 causes the CPU 1 to read the positions of the vibration-proof lens 13 in the X and

25 the Y direction through the X and the Y axis lens position detecting circuit 6 and 7. In the following description, a mechanism for shifting the vibration-

proof lens 13 by the rotation of the X and the Y axis motor 4 and 5 is referred to as "vibration-proof lens shifting mechanism."

[0022]

5           On the communication tool side, there is provided a communication tool 15 electrically connected to the CPU 1 of the camera. The communication tool 15 transmits information to and receives it from the CPI 1 to perform various adjustments of the camera in  
10   synchronization with the operation of the camera. On the shaking table side, there is provided a shaking table 18 electrically connected to the communication tool 15. The shaking table 18 serves to shake the camera and shakes in a substantially sinusoidal wave  
15   shape in the X and the Y axis direction being the shift direction of the vibration-proof lens 13 in accordance with instructions from the communication tool 15 with the camera attached thereto.

[0023]

20           The adjustment of dispersion in gain and displacement in the detection angle of the angular velocity in the angular velocity detection is described below.

(1) Method of adjusting gain and correcting angle  
25   displacement

          The yaw and the pitch angular velocity detecting circuit 8 and 9 are formed of angular velocity sensors

and amplifier circuits for amplify the signals thereof. Factors of dispersion in gain include dispersion in the outputs of the angular velocity sensors and the amplification factors of the amplifier circuits.

- 5 Furthermore, in the camera in which the CPU 1 performs the A/D conversion like the present embodiment, the factors also include dispersion in the A/D converters in an individual CPU 1 or the reference voltage used in the A/D conversion. Figure 2 is a schematic diagram  
10 illustrating dispersion in the gains of the yaw and the pitch angular velocity detecting circuit 8 and 9. Factors of dispersion in the gains in the yaw and the pitch direction are simply taken as G1 and G2 respectively.

15 [0024]

- The detection directions of the angular velocities of the yaw and the pitch angular velocity detecting circuit 8 and 9 do not accurately coincide with the move direction of the vibration-proof lens 13 based on  
20 the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9, so that an error caused by an angle displacement is produced therebetween. Figure 3 is a chart describing the angle displacement. In Figure 3, the abscissa and the ordinate indicate the X  
25 and the Y axis drive direction of the vibration-proof lens 13 respectively. The X axis drive direction is displaced by an angle  $\alpha$  with respect to the detection



direction of angular velocity by the yaw angular velocity detecting circuit 8. On the other hand, the Y axis drive direction is displaced by an angle  $\beta$  with respect to the detection direction of angular velocity by the pitch angular velocity detecting circuit 9. In this case, if a vector  $\omega$  (the magnitude is  $\omega$  and an angular velocity tilted counterclockwise by  $\theta$  from the X axis drive axis direction) is given by hand shake, the outputs "u" and "v" of the yaw and the pitch angular velocity detecting circuit 8 and 9 are calculated by the following equations (Expression 1) and (Expression 2):

$$\text{(Expression 1)} \quad u = G1 \times \omega \times \cos (\theta + \alpha)$$

$$\text{(Expression 2)} \quad v = G2 \times \omega \times \sin (\theta - \beta),$$

where, in Figure 3, gain dispersions G1 and G2 are taken as one respectively ( $G1 = G2 = 1$ ) for better understanding.

[0025]

The outputs u1 and v1 of the yaw and the pitch angular velocity detecting circuit 8 and 9 in the case where the angular velocity applied to the camera is  $\omega 1$  in magnitude and the X axis direction (i.e.,  $\theta = 0$ ) in the direction thereof are calculated by the following equations (Expression 3) and (Expression 4):

$$\text{(Expression 3)} \quad u1 = G1 \times \omega 1 \times \cos (\alpha)$$

$$\text{(Expression 4)} \quad v1 = - G2 \times \omega 1 \times \sin (\beta).$$

[0026]

The outputs  $u_2$  and  $v_2$  of the yaw and the pitch angular velocity detecting circuit 8 and 9 in the case where the angular velocity applied to the camera is  $\omega_2$  in magnitude and the Y axis direction (i.e.,  $\theta = 90^\circ$ ) in the direction thereof are calculated by the following equations (Expression 5) and (Expression 6):

(Expression 5)  $u_2 = -G_1 \times \omega_2 \times \sin(\alpha)$

(Expression 6)  $v_2 = G_2 \times \omega_2 \times \cos(\beta)$ .

[0027]

10 The gain dispersions  $G_1$  and  $G_2$  of the yaw and the pitch angular velocity detecting circuit 8 and 9 are calculated by the following equations (Expression 7) and (Expression 8) derived from the equations (Expression 3) and (Expression 6):

15 (Expression 7)  $G_1 = u_1/(\omega_1 \times \cos(\alpha))$

(Expression 8)  $G_2 = u_2/(\omega_2 \times \cos(\beta))$ ,

where, since angle displacements  $\alpha$  and  $\beta$  in the detection direction with respect to the X and the Y axis are approximately  $5^\circ$  at the most, even if  $\cos(\alpha) = 1$  and  $\cos(\beta) = 1$ , the gain dispersions  $G_1$  and  $G_2$  can be approximated within an error of about 0.4%.

20 Accordingly, the equations (Expression 7) and (Expression 8) can be approximated as expressed by the following equations (Expression 9) and (Expression 10) respectively:

(Expression 9)  $G_1 = u_1/\omega_1$

(Expression 10)  $G_2 = v_2/\omega_2$ .

[0028]

Thus, the gain dispersions G1 and G2 can be calculated by the output values of the yaw and the pitch angular velocity detecting circuit 8 and 9 in the case where predetermined angular velocities are applied to the X and the Y axis. In Figure 2, the G1 and the G2 are calculated by the above method. The output values of the yaw and the pitch angular velocity detecting circuit 8 and 9 are multiplied by the gain adjustment value A1 in the yaw direction proportional to the inverse number of the G1 and the gain adjustment value A2 in the pitch direction proportional to the inverse number of the G2 to correct the gain dispersions. The output values U and V of the yaw and the pitch angular velocity detecting circuit 8 and 9 in which the gain dispersions have been corrected are calculated by the following equations (Expression 11) and (Expression 12):

$$\text{(Expression 11)} \quad U = A1 \times G1 \times \omega \times \cos (\theta + \alpha)$$

$$\text{(Expression 12)} \quad V = A2 \times G2 \times \omega \times \sin (\theta - \beta).$$

[0029]

The detection angle displacements  $\alpha$  and  $\beta$  are calculated by the following equations (Expression 13) and (Expression 14) derived from the equations (Expression 3) and (Expression 5) and the equations (Expression 4) and (Expression 6) respectively:

$$\text{(Expression 13)} \quad \tan (\alpha) = - (\omega 1 / \omega 2) \times (u 2 / u 1)$$

(Expression 14)  $\tan (\beta) = - (\omega_2/\omega_1) \times (v_1/v_2),$

where, since the displacements  $\alpha$  and  $\beta$  in the detection direction with respect to the X and the Y axis are

approximately  $5^\circ$  at the most, even if  $\cos (\alpha) = 1$  and

5  $\cos (\beta) = 1$ , approximation is possible within an error of about 0.4%. Accordingly, the equations (Expression 13) and (Expression 14) can be approximated as expressed by the following equations (Expression 15) and (Expression 16) respectively:

10 (Expression 15)  $\sin (\alpha) = - (\omega_1/\omega_2) \times (u_2/u_1)$

(Expression 16)  $\sin (\beta) = - (\omega_2/\omega_1) \times (v_1/v_2).$

[0030]

Thus, the angle displacements  $\alpha$  and  $\beta$  in the detection direction of the yaw and the pitch angular  
15 velocity detecting circuit 8 and 9 can be calculated by the output values of the yaw and the pitch angular velocity detecting circuit 8 and 9 in the case where predetermined angular velocities are applied to the X and the Y axis.

20 [0031]

The following is a description of a method of correcting the angle displacement of an actual camera at the time of calculating the gain dispersions  $G_1$  and  $G_2$  and angle displacements  $\alpha$  and  $\beta$  using the above  
25 method. For the simplicity of description, if the equations (Expression 11) and (Expression 12) are normalized with  $A_1 \times G_1$  taken as 1 and  $A_2 \times G_2$  taken as

1, the output values U and V of the yaw and the pitch angular velocity detecting circuit 8 and 9 after the correction of the gain dispersions G1 and G2 can be represented by the following equations (Expression 17)

5 and (Expression 18):

$$\text{(Expression 17)} \quad U = \omega \times \cos (\theta + \alpha)$$

$$\text{(Expression 18)} \quad V = \omega \times \sin (\theta - \beta).$$

The angular velocities X and Y in the X and the Y axis direction are calculated by the following

10 equations (Expression 19) and (Expression 20):

$$\text{(Expression 19)} \quad X = \omega \times \cos (\theta)$$

$$\text{(Expression 20)} \quad Y = \omega \times \sin (\theta).$$

If the equations (Expression 17) and (Expression 18) are rendered independent of  $\theta$ , the equations can be represented by the following equations (Expression 21) and (Expression 22):

$$\text{(Expression 21)} \quad X = (\cos (\beta) / \cos (\alpha + \beta)) \times U + (\sin (\alpha) / \cos (\alpha + \beta)) \times V$$

$$\text{(Expression 22)} \quad Y = (\cos (\alpha) / \cos (\alpha + \beta)) \times V + (\sin (\beta) / \cos (\alpha + \beta)) \times U.$$

[0032]

Where, since the displacements  $\alpha$  and  $\beta$  in the detection direction with respect to the X and the Y axis are approximately  $5^\circ$  at the most, if  $\cos (\alpha)$ ,  $\cos (\beta)$  and  $\cos (\alpha + \beta)$  are approximated to one respectively, the equations (Expression 21) and (Expression 22) can be approximated as expressed by the

25

following equations (Expression 23) and (Expression 24) respectively:

$$\text{(Expression 23)} \quad X = U + \sin(\alpha) \times V$$

$$\text{(Expression 24)} \quad Y = V + \sin(\beta) \times U,$$

- 5 in other words, if the gain dispersions are calculated by the equations (Expression 9) and (Expression 10) and the sin values of angle displacements are calculated by the equations (Expression 14) and (Expression 15), the gain dispersions G1 and G2 and the angle displacements  
10  $\alpha$  and  $\beta$  can be corrected by the equations (Expression 23) and (Expression 24).

[0033]

- The correction of the gain dispersions G1 and G2 and the angle displacements  $\alpha$  and  $\beta$  is described below  
15 with reference to Figure 2. The outputs "u" and "v" of the yaw and the pitch angular velocity detecting circuit 8 and 9 with the gain dispersions G1 and G2 are multiplied by gain adjustment values A1 and A2 respectively to obtain the gain-adjusted outputs U and  
20 V. The sum of the output U and the output in which the output V is multiplied by an angle displacement adjustment value  $\Delta\alpha$  is taken as X and the sum of the output V and the output in which the output U is multiplied by an angle displacement adjustment value  $\Delta\beta$   
25 is taken as Y. Where, the angle displacement adjustment value  $\Delta\alpha = \sin(\alpha)$  and  $\Delta\beta = \sin(\beta)$ . That is to say, the configuration illustrated in Figure 2

provides the angular velocities  $X$  and  $Y$  in the  $X$  and the  $Y$  axis direction. After that, the angular velocities  $X$  and  $Y$  are multiplied by  $B$  to obtain target velocities  $V_c(X)$  and  $V_c(Y)$  at which the vibration-proof lens 13 is shifted in the  $X$  and the  $Y$  axis direction (hereinafter, referred to as "target velocity of vibration-proof lens"). Where,  $B$  is a coefficient which determines a velocity at which the vibration-proof lens 13 is shifted with respect to a predetermined angle velocity (hereinafter, referred to as an "angular-velocity to vibration-proof lens target-velocity converting coefficient." That is to say, multiplying the calculated angular velocities  $X$  and  $Y$  in each driving axis direction by  $B$  calculates the vibration-proof lens target-velocities  $V_c(X)$  and  $V_c(Y)$  in each direction. After the vibration-proof lens target-velocities  $V_c(X)$  and  $V_c(Y)$  have been calculated, the vibration-proof lens 13 is shifted at each velocity to enable hand shake on an image surface to be cancelled.

[0034]

(2) An adjustment method using a shaking table sinusoidally varying an angular velocity

In the above description, gain adjustment and angle displacement adjustment can be performed by continuously applying a constant angular velocity to a camera to detect the output values of the yaw and the

pitch angular velocity detecting circuit 8 and 9 during that application. Actually, however, it is very difficult to accurately apply a constant angular velocity to a camera. The reason is that an accurate application of a constant angular velocity to a camera needs to cause the camera to perform uniform rotational motion with the camera fixed at a given distance around at a point. That is why the shaking table 18 is used to apply a sinusoidally varying angular velocity to a camera to perform the gain adjustment and the angle displacement adjustment.

[0035]

One end around the shaking portion of the shaking table 18 is fixed and a properly flattened cam is arranged under around the opposite end thereof. The cam is rotated by a motor to sinusoidally move the shaking portion upward and downward. The shaking table 18 has the mechanisms in two directions. The camera is attached to the table so that the X and the Y axis drive direction of the vibration-proof lens 13 coincide with the shake directions. Actually, there exists a subtle angle displacement between the drive direction of the vibration-proof lens 13 and the shake direction, however, the angle displacement is smaller enough to be negligible than the angle displacement that matters in the present invention.

[0036]



Referring to Figure 4, an embodiment is described below in which a sinusoidal angular velocity is applied to a camera to perform the gain adjustment and the angle displacement adjustment. Figure 4 is a chart illustrating how the gain and the angle displacement are adjusted according to the present invention. Firstly, a sinusoidal angular velocity with a total amplitude  $\omega_1$  is applied to a camera in the X axis driving direction of the vibration-proof lens 13 by the shaking table 18. At this point, the maximum and the minimum output value of the yaw angular velocity detecting circuit 8 are taken as  $u_{lmax}$  and  $u_{lmin}$  respectively and the maximum and the minimum output value of the pitch angular velocity detecting circuit 9 are taken as  $v_{lmax}$  and  $v_{lmin}$  respectively. Secondly, a sinusoidal angular velocity with a total amplitude  $\omega_2$  is applied to the camera in the Y axis driving direction of the vibration-proof lens 13 by the shaking table 18. At this point, the maximum and the minimum output value of the yaw angular velocity detecting circuit 8 are taken as  $u_{2max}$  and  $u_{2min}$  respectively and the maximum and the minimum output value of the pitch angular velocity detecting circuit 9 are taken as  $v_{2max}$  and  $v_{2min}$  respectively.

[0037]

The gain dispersion at this point can be regarded similar as that in the case where the above constant

angular velocity is applied. If a sinusoidal angular velocity is applied to the camera, the gain dispersions G1 and G2 are calculated as a ratio of the total amplitude of the applied angular velocity and the total amplitude of the output value as represented by the following equations (Expression 25) and (Expression 26) respectively:

$$\text{(Expression 25) } G1 = (u_{\text{max}} - u_{\text{min}})/\omega_1$$

$$\text{(Expression 26) } G2 = (v_{\text{2max}} - v_{\text{2min}})/\omega_2.$$

Therefore, the gain adjustment values A1 and A2 are calculated as values proportional to the inverse numbers of the G1 and the G2 respectively. Alternately, the gain adjustment values A1 and A2 are given as the ratio of the total amplitudes of the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 rendered the target value desired to be obtained after the gain adjustment to the total amplitudes  $\omega_1$  and  $\omega_2$  of the applied angular velocities. If the target total amplitudes of the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 are U1 and V1 respectively after the gain adjustment, the gain adjustment values A1 and A2 are calculated by the following equations (Expression 27) and (Expression 28) respectively:

$$\text{(Expression 27) } A1 = U1/(u_{\text{max}} - u_{\text{min}})$$

$$\text{(Expression 28) } A2 = V1/(v_{\text{2max}} - v_{\text{2min}}).$$

[0038]

The angle displacement in the detection direction of the yaw and the pitch angular velocity detecting circuit 8 and 9 may also be regarded similar as that in the case where the above constant angular velocity is applied. If a sinusoidal angular velocity is applied to the camera, the angle displacement is calculated by the following equations (Expression 29) and (Expression 30) respectively:

$$\text{(Expression 29) } \sin(\alpha) = -f * (\omega_1/\omega_2) \times \{(u_{2\max} - u_{2\min}) / (u_{1\max} - u_{1\min})\}$$

$$\text{(Expression 30) } \sin(\beta) = -c * (\omega_2/\omega_1) \times \{(v_{1\max} - v_{1\min}) / (v_{2\max} - v_{2\min})\},$$

where, "c" and "f" are given by the following equations (Expression 31) and (Expression 32) respectively:

(Expression 31)  $c = +1$  ( $v_1$  is positive at the time of detecting  $u_{1\max}$  when the angular velocity is applied in the X axis)

$c = -1$  ( $v_1$  is negative at the time of detecting  $u_{1\max}$  when the angular velocity is applied in the X axis)

(Expression 32)  $f = +1$  ( $u_2$  is positive at the time of detecting  $v_{2\max}$  when the angular velocity is applied in the Y axis)

$f = -1$  ( $u_2$  is negative at the time of detecting  $v_{2\max}$  when the angular velocity is applied in the Y axis)

[0039]

Since the values of the total amplitudes calculated from the maximum and the minimum value at the time of applying the sinusoidal angular velocity to the camera are always positive, the sign of the angle displacement is unknown. To avoid that, in the equation (Expression 31), if the angular velocity applied in the X axis direction is positive, the output of the pitch angular velocity detecting circuit 9 is the same in sign as that at the time of detecting the maximum output value  $ul_{max}$  of the yaw angular velocity detecting circuit 8, so that the sign of angle displacement is detected using the above (as is the case with the equation (Expression 32)). In the present embodiment, although the above method is used to detect the sign of angle displacement for purpose of simplification, the sign of output of an angular velocity detecting circuit in the opposite direction at the time of detecting the minimum value or the sign of the angular velocity applied by the shaking table 18 may be compared with the signs of outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 to detect the sign of the angle displacement.

[0040]

Here, the problem is that, unless the shaking table 18 is accurately controlled, the above maximum and the minimum value cannot be accurately calculated

when the gain adjustment and the angle displacement adjustment are performed by applying a sinusoidally varying angular velocity to a camera angular velocity using the shaking table 18. This is firstly because if  
5 the frequency of the angular velocity applied by the shaking table 18 is varied due to wow and flutter of the drive motor of the shaking table 18, the total amplitudes of the output values of the yaw and the pitch angular velocity detecting circuit 8 and 9 are  
10 varied in proportion to the amount of variation, causing an error in a gain adjustment value and an angle displacement adjustment value, and secondly because if the shaking table 18 does not operate smoothly to shake the camera with a high frequency,  
15 noises according to the shake are superposed on the output values of the yaw and the pitch angular velocity detecting circuit 8 and 9 to produce an error in the detection of the maximum and the minimum value of the output value of each angular velocity detecting circuit,  
20 causing an error in a gain adjustment value and an angle displacement adjustment value. A method of resolving the problems is described below.  
Incidentally, if the above problem is not found when these adjustments are made using an accurate shaking  
25 table, it is needless to say that the above adjustment method is available.

[0041]

(3) An adjustment method using an integral value of an angular velocity

The above adjustment method is performed by the dimension of an angular velocity. The following

5 adjustment method is performed by the dimension of an angle or a position. First, an initial value is set to the gain adjustment values in the yaw and the pitch direction as represented by the following equation (Expression 33) and the angle displacement adjustment  
10 values  $\Delta\alpha$  and  $\Delta\beta$  are cleared as represented by the equation (Expression 34):

(Expression 33)  $A1 = A2 = A0$

(Expression 34)  $\Delta\alpha = \Delta\beta = 0.$

This outputs the angular velocities X and Y in the  
15 detection directions in which the gain adjustment and the angle displacement correction are not performed in Figure 2. Secondly, the vibration-proof lens target velocities  $V_c(X)$  and  $V_c(Y)$  in the X and the Y axis direction in which the outputs (the angular velocities  
20 X and Y) are multiplied by B are integrated as represented by the following equations (Expression 35) and (Expression 36) respectively, calculating target positions LC (X) and LC (Y) in the X and the Y axis direction of the vibration-proof lens 13:

25 (Expression 35)  $LC(X) = \int V_c(X)$

(Expression 36)  $LC(Y) = \int V_c(Y).$

[0042]

On the other hand, the target positions LC (X) and LC (Y) of the vibration-proof lens 13 are preferably calculated by accumulating the target velocities  $V_c(X)$  and  $V_c(Y)$  at a predetermined time interval instead of the integrals represented by the equations (Expression 35) and (Expression 36) in the case where the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 are A/D converted by, for example, the CPU 1 and the subsequent process is controlled using digital values. In this case, the target positions LC (X) and LC (Y) of the vibration-proof lens 13 may be calculated by accumulation.

[0043]

A sinusoidal shake vibration with an angular total-amplitude  $\gamma_1$  is applied to the camera in the X axis direction of the vibration-proof lens 13 by the shaking table 18. If the maximum and the minimum value of the target position LC (X) are taken as  $LC_{max}(X)$  and  $LC_{min}(X)$  respectively, and the maximum and the minimum value of the target position LC (Y) are taken as  $LC_{max}(Y)$  and  $LC_{min}(Y)$  respectively, the total amplitudes "a" and "b" of the vibration-proof lens target-positions of the X and the Y axis are calculated from the following equations (Expression 37) and (Expression 38) respectively. In addition, "c" is calculated by a sign of the target position LC (Y) at the time of detecting the  $LC_{max}(X)$  from the equation

(Expression 39):

(Expression 37)  $a = LC_{\max}(X) - LC_{\min}(X)$

(Expression 38)  $b = LC_{\max}(Y) - LC_{\min}(Y)$

(Expression 39)  $c = +1$  (LC(Y) is positive at the time  
5 of detecting  $LC_{\max}(X)$ )

$C = -1$  (LC(Y) is negative at the time  
of detecting  $LC_{\max}(X)$ ).

[0044]

A sinusoidal shake vibration with an angular  
10 total-amplitude  $\gamma_2$  is applied to the camera in the Y  
axis driving direction of the vibration-proof lens 13  
by the shaking table 18. If the maximum and the  
minimum value of the target position LC (X) are taken  
as  $LC_{\max}(X)$  and  $LC_{\min}(X)$  respectively, and the maximum  
15 and the minimum value of the target position LC (Y) are  
taken as  $LC_{\max}(Y)$  and  $LC_{\min}(Y)$  respectively, the total  
amplitudes "d" and "e" of the vibration-proof lens  
target-positions of the X and the Y axis are calculated  
from the following equations (Expression 40) and  
20 (Expression 41) respectively. In addition, "f" is  
calculated by a sign of the target position LC (X) at  
the time of detecting the  $LC_{\max}(Y)$  from the equation  
(Expression 42):

(Expression 40)  $d = LC_{\max}(X) - LC_{\min}(X)$

25 (Expression 41)  $e = LC_{\max}(Y) - LC_{\min}(Y)$

(Expression 42)  $f = +1$  (LC(X) is positive at the time  
of detecting  $LC_{\max}(Y)$ )



$f = -1$  (LC(X) is negative at the time of detecting LCmax(Y)).

[0045]

If the total amplitudes of the vibration-proof lens target positions LC (X) and LC (Y) in the X and the Y axis direction desired to be obtained after gain adjustment are taken as L01 and L02 respectively with respect to the angular total-amplitudes  $\gamma_1$  and  $\gamma_2$  applied by the shaking table 18, the gain adjustment values A1 and A2 are calculated by the following equations (Expression 43) and (Expression 44) respectively. Where, L01 and L02 are proportional to the angular total-amplitudes  $\gamma_1$  and  $\gamma_2$  and are the total amplitudes of shift of the vibration-proof lens 13 being proper to stop an image with respect to shake-angular total-amplitudes. The value is determined by a photographing optical system and the theoretical value thereof is calculated.

(Expression 43)  $A1 = A0 \times L01/a$

20 (Expression 44)  $A2 = A0 \times L02/e$

[0046]

The equations (Expression 43) and (Expression 44) convert the angular velocities represented by the equations (Expression 27) and (Expression 28) to dimensions of the vibration-proof lens target positions being integral values of the angular velocities. The equations (Expression 43) and (Expression 44) calculate

a multiplier by which an initial value A0 of the gain adjustment value is multiplied from the ratio of the vibration-proof lens amplitudes before the gain adjustment to the amplitudes of the vibration-proof lens target positions desired to be obtained in the case where the gain adjustment value is an initial value A0 and the initial value A0 is multiplied by the multiplier to calculate the gain adjustment value.

[0047]

10        Angle displacement correction amounts  $\Delta\alpha$  and  $\Delta\beta$  in the detection directions of the yaw and the pitch angular velocity detecting circuit 8 and 9 are calculated by the following equations (Expression 45) and (Expression 46) respectively:

15        (Expression 45)  $\Delta\alpha = \sin(\alpha) = -f * (L01/L02) \times (d/a)$   
           (Expression 46)  $\Delta\beta = \sin(\beta) = -c * (L02/L01) \times (b/e)$ ,  
           the equations (Expression 45) and (Expression 46) convert the angular velocities represented by the equations (Expression 29) and (Expression 30) to

20        dimensions of the vibration-proof lens target positions being integral values of the angular velocities.

[0048]

          Performing the gain adjustment and the angle displacement adjustment by integral values of the

25        outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 using the above method hardly varies the angular amplitude of the shaking table 18

even if the frequency of the shaking table 18 varies in some degree. Even if a vibration noise is slightly superposed on the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 at the time of applying vibration by the shaking table 18, calculation is performed from the integral values of the outputs, so that the adjustment can be made substantially independently of the influence of the noise.

10 [0049]

An embodiment of adjustment process of an actual camera is described below. The adjustment process is divided into a communication-tool adjustment process performed on the communication tool side and a camera communication-mode process formed on the camera side. The outline of the general adjustment process is described. As illustrated in Figure 1, the CPU 1 of the camera is electrically connected to the communication tool 15 to perform the adjustment process of the camera. In the following description, motors 4 and 5 are controlled by a pulse width modulation (PWM). In general, the PWM control is a method in which an energizing time is made variable during a certain period of time, that is to say, duty at which the motors 4 and 5 are turned on is made variable, thereby performing speed control. Figure 7 is a flow chart illustrating one embodiment of a communication

adjustment process performed by the communication tool

15. Figure 8 is a flow chart following Figure 7.

Figure 9 is a flow chart following Figure 8. In

Figures 7 to 9, the communication tool 15 inspects

5 whether the vibration-proof lens shifting mechanism  
normally operates at steps S602 to S607 and performs  
the gain adjustment and the detection angle

displacement adjustment of the yaw and the pitch

angular velocity detecting circuit 8 and 9 at steps

10 S608 to S624. In addition, the communication tool 15  
performs the total inspection of vibration-proof  
controllability at steps S625 to S646.

[0050]

Figure 10 is a flow chart illustrating one

15 embodiment of the communication-mode process performed  
by the CPU 1 of the camera. The CPU 1 of the camera  
starts the communication-mode process of the camera  
according to instructions from the communication tool  
15. The CPU 1 performs, for example, a vibration-proof  
20 lens resetting process at step S704 and a vibration-  
proof-control starting process at step S709 in response  
to instructions from the communication tool 15.

[0051]

(1) Process on the camera side

25 The communication-mode process on the camera side  
is described in detail with reference to Figure 10.  
When the communication tool process is started at step

S600 in Figure 7, the communication tool 15 transmits an instruction to perform the communication-mode process to the CPU 1 of the camera at the following step S601. Thereby, the CPU 1 of the camera starts the communication-mode process at step S700 in Figure 10 and proceeds to the following step S701. At step S701, the initial value A0 is set to the angular velocity gain adjustment values A1 and A2 by the equation (Expression 33). The angle displacement adjustment values  $\Delta\alpha$  and  $\Delta\beta$  are cleared by the equation (Expression 34) at the following step S702 and the process proceeds to step S703. The processes S703 to S718 are branched depending on the kind of instruction from the communication tool 15. At step S703, a determination is made as to whether a vibration-proof lens resetting instruction is issued. If the instruction is issued, the vibration-proof lens resetting process (refer to Figure 11) is performed at step S704 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S705. At step S705, a determination is made as to whether a vibration-proof lens centering instruction is issued. If the instruction is issued, a vibration-proof lens centering process (refer to Figure 12) is performed at step S706 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S707.

[0052]

At step S707, a determination is made as to whether a vibration-proof adjustment starting instruction is issued. If the instruction is issued, a vibration-proof-control starting process (refer to Figure 13) is performed at step S709 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S708. At step S708, a determination is made as to whether a vibration-proof control starting instruction is issued. If the instruction is issued, a vibration-proof-control starting process is performed at step S709 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S710. At step S710, a determination is made as to whether a vibration-proof adjustment ending instruction is issued. If the instruction is issued, a vibration-proof-control timer interrupt process is disabled at step S712, the vibration-proof-control is ended and the process returns to step S703. If the instruction is not issued, the process proceeds to step S711. At step S711, a determination is made as to whether a vibration-proof control ending instruction is issued. If the instruction is issued, a vibration-proof-control timer interrupt process is disabled at step S712, the vibration-proof-control is ended and the process returns to step S703. If the instruction is not issued,

the process proceeds to step S713.

[0053]

At step S713, a determination is made as to whether a data read instruction is issued. If the  
5 instruction is issued, data specified by the communication tool 15 is transferred to the communication tool 15 at step S714 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S715. At step S715, a  
10 determination is made as to whether a data write instruction is issued. If the instruction is issued, data transferred by the communication tool 15 is written in data specified by the communication tool 15 at step S716 and the process returns to step S703. If  
15 the instruction is not issued, the process proceeds to step S717. At step S717, a determination is made as to whether an E2PROM write instruction is issued. If the instruction is issued, data transferred by the communication tool 15 is written in data in the E2PROM  
20 specified by the communication tool 15 at step S718 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S719. At step S719, a determination is made as to whether a communication mode release instruction is issued. If  
25 the instruction is issued, the communication mode process of the camera is ended at step S720. If the instruction is not issued, the process proceeds to step

S703. As described above, according to the instruction of the communication tool 15, the camera performs processes corresponding to the instruction.

[0054]

5           Figure 11 is a flow chart illustrating one embodiment of the vibration-proof lens resetting process at step S704 in Figure 10. The process proceeds to step S800 from step S704 to start the vibration-proof lens resetting process. At step S801, 10 the vibration-proof lens resetting timer interrupt process (refer to Figure 14) is permitted to start resetting the vibration-proof lens 13. At step S802, the process waits for a predetermined time (for example, 10 ms) and proceeds to step S803. At step S803, a 15 determination is made as to whether the vibration-proof lens velocity  $VR(X)$  of the X axis is equal to a predetermined value or less, that is to say, the resetting drive of the vibration-proof lens of the X axis is ended. If the velocity is equal to a 20 predetermined value or less, the process proceeds to step S804. If not, the process returns to step S803. At step S804, a determination is made as to whether the vibration-proof lens velocity  $VR(Y)$  of the Y axis is equal to a predetermined value or less, that is to say, 25 the resetting drive of the vibration-proof lens of the Y axis is ended. If the velocity is equal to a predetermined value or less, the process proceeds to



step S805 to end the resetting process of the vibration-proof lens. If not, the process returns to step S803.

[0055]

5           Therefore, the processes at steps S803 and S804 are repeated until the vibration-proof lens resetting drive process of both the X and the Y axis is ended. After the process of both the axes is ended, the process is ended at step S805. Whether the vibration-  
10 proof lens resetting drive is ended is determined based on whether the velocities VR(X) and VR(Y) of the vibration-proof lens 13 become equal to substantially zero when the vibration-proof lens 13 reaches the reset end being one end of the control range thereof. The  
15 reason the process waits for a predetermined time at step S802 is that an erroneous determination is prevented at the processes S803 and S804 caused by the rise of the velocities VR(X) and VR(Y) of the vibration-proof lens 13 from substantially zero at the  
20 initial stage of reset drive thereof.

[0056]

Figure 14 is a flow chart illustrating one embodiment of the vibration-proof lens resetting timer interrupt process at step S801 in Figure 11.

25 Practically, two vibration-proof lens resetting timer interrupt processes for the X and the Y axis are performed, but both processes are the same, so that the

process only on the X axis side is described and the process on the Y axis side is omitted. The process is repeated at a predetermined interval (for example, 1 ms). When the present vibration-proof lens resetting timer interrupt process is permitted at step S801, the vibration-proof lens position LR(X) set at the preceding vibration-proof lens resetting timer interrupt process is set to LR'(X) at step S1101. The position of the X axis of the vibration-proof lens 13 detected by the X axis lens position detecting circuit 6 is set to LR(X) at step S1102. At step S1103, LR'(X) is subtracted from LR(X) to calculate variation in position of the vibration-proof lens 13 during a predetermined time period, i.e., the velocity VR(X) of the vibration-proof lens 13 in the X axis direction. At the following step S1104, the motor 4 is driven at a predetermined drive duty to drive the vibration-proof lens 13 to a reset position in the X axis direction. The present vibration-proof lens resetting timer interrupt process is ended at step S1105.

[0057]

Figure 12 is a flow chart illustrating one embodiment of the vibration-proof lens centering process at step S706 in Figure 10. The vibration-proof lens centering process drives the vibration-proof lens 13 to a center position LS. The process proceeds to step S900 from step S706 to start process. At step

S901, there are cleared a vibration-proof lens stop FLG and FLGs to be set if abnormality is detected (such as a vibration-proof lens centering time-out abnormality FLG, an X and a Y axis vibration-proof lens motion abnormality FLG and an X and a Y axis vibration-proof lens position detection abnormality FLG). At the following step S902, a vibration-proof lens centering process interrupt time-out time is set. The time to be set here refers to such a time that the vibration-proof lens 13 is surely driven to the center position within the set time unless any abnormality is generated after the centering process has started.

[0058]

At step S903, the vibration-proof lens centering timer interrupt process (refer to Figure 15) is permitted to start a vibration-proof lens centering control. At step S904, the process waits for a predetermined time. At step S905, there are cleared the maximum values VRmax (X) and VRmax (Y) of each of velocities of the X and the Y axis of the vibration-proof lens 13 and the minimum values VRmin (X) and VRmin (Y) of each of velocities of the X and the Y axis thereof.

[0059]

The reason the process waits for a predetermined time at step S904 is described below. In general, the X and the Y axis lens position detecting circuit 6 and

7 use such a configuration that, for example, variation  
in position of the vibration-proof lens 13 is detected  
by the number of counts of interrupter signal pulse.  
In the above detection method, the interrupter signal  
5 is a discrete signal, so that the number of pulses  
entering during the predetermined time or the inverse  
number of period of the interrupter signal can detect  
the vibration-proof lens velocity VR. However, at the  
beginning of start of the centering control of the  
10 vibration-proof lens 13, an accurate vibration-proof  
lens velocity cannot be detected or an impossible high  
value can be detected. For that reason, even if the  
interrupter is used, the process waits for a  
predetermined time period after the centering control  
15 has started. After an accurate vibration-proof lens  
velocity has been calculated, there are cleared VRmax  
(X), VRmax (Y), VRmin (X) and VRmin (Y). Incidentally,  
a waiting time at step S904 is usually set to about 5  
ms to about 10 ms. VRmax (X), VRmax (Y), VRmin (X) and  
20 VRmin (Y) are detected by the vibration-proof lens  
centering timer interrupt process (Figure 15).  
[0060]

At step S906, a determination is made as to  
whether a vibration-proof lens centering process  
25 interrupt timer set at step S902 is timed out, that is  
to say, whether a predetermined time period has passed  
after the centering control of the vibration-proof lens

13 was started. If the time has passed, it is determined as abnormal and the process proceeds to step S907 to set the vibration-proof lens centering time-out abnormality FLG and proceeds to step S918. On the other hand, if the time has not passed, the process proceeds to step S908 to determine as to whether the VR max(X) is equal to a predetermined value or less. If the value is equal to the predetermined value or less, it is determined as abnormal in motion in the X axis direction of the vibration-proof lens 13. The process proceeds to step S909 to set the X axis vibration-proof lens motion abnormality FLG and proceeds to step S918. On the other hand, if the value is not equal to the predetermined value or less, the process proceeds to step S910.

[0061]

At step S910, a determination is made as to whether the VR max(Y) is equal to a predetermined value or less. If the value is equal to the predetermined value or less, it is determined as abnormal in motion in the Y axis direction of the vibration-proof lens 13. The process proceeds to step S911 to set the Y axis vibration-proof lens motion abnormality FLG and proceeds to step S918. On the other hand, if the value is not equal to the predetermined value or less, the process proceeds to step S912. The processes at steps S908 and S910 determine the abnormality of motion of

the vibration-proof lens 13 using the maximum values VRmax(X) and VRmax(Y) of the vibration-proof lens velocities becoming small when the vibration-proof lens 13 is out of order. The maximum values VRmax(X) and VRmax(Y) may be determined based on whether the vibration-proof lens velocities VR(X) and VR(Y) are equal to a predetermined value or less.

[0062]

At step S912, a determination is made as to whether the VRmin(X) is equal to a predetermined value or less. If the value is equal to the predetermined value or less, it is determined as abnormal in an X axis lens position detection. The process proceeds to step S913 to set the X axis vibration-proof lens position detection abnormality FLG and proceeds to step S918. On the other hand, if the value is not equal to the predetermined value or less, the process proceeds to step S914. At step S914, a determination is made as to whether the VRmin(Y) is equal to a predetermined value or less. If the value is equal to the predetermined value or less, it is determined as abnormal in an Y axis lens position detection. The process proceeds to step S915 to set the Y axis vibration-proof lens position detection abnormality FLG and proceeds to step S918. On the other hand, if the value is not equal to the predetermined value or less, the process proceeds to step S916. The processes at

steps S912 and S914 determine the abnormality of output of the X and the Y axis lens position detecting circuit 6 and 7 using an abnormality value to be set to the VRmin(X) and the VRmin(Y) when the vibration-proof lens velocities VR(X) and VR(Y) being the outputs of the X and the Y axis lens position detecting circuit 6 and 7 are calculated as abnormal values and impossible small values (for example, values with negative signs) and detected in the vibration-proof lens centering timer interrupt (Figure 15). The minimum values VRmin(X) and VRmin(Y) may be determined based on whether the vibration-proof lens velocities VR(X) and VR(Y) are equal to a predetermined value or less.

[0063]

At step S916, a determination is made as to whether the operation of the vibration-proof lens 13 in the X axis direction of is stopped. If the operation is stopped, the process proceeds to step S917. If the operation is not stopped, the process returns to step S906. The determination as to whether the operation of the vibration-proof lens 13 is stopped is made by the X axis vibration-proof lens stop FLG. The X axis vibration-proof lens stop FLG is set when the X axis vibration-proof lens position LR(X) set at the vibration-proof lens centering timer interrupt process reaches the front of a predetermined value Lstop of the center position LS. At step S917, as is the case with

step S916, a determination is made as to whether the operation of the vibration-proof lens 13 in the Y axis direction is stopped. If the operation is stopped, the process proceeds to step S918. If the operation is not  
5 stopped, the process returns to step S906. The determination as to whether the operation of the vibration-proof lens 13 is stopped is made by the Y axis vibration-proof lens stop FLG as is the case with above. The Y axis vibration-proof lens stop FLG is set  
10 when the Y axis vibration-proof lens position LR(Y) set at the vibration-proof lens centering timer interrupt process reaches the front of a predetermined value Lstop of the center position LS.  
[0064]

15 The processes at steps S916 and S917 repetitively execute the processes at the steps S906 to S917 until the positions of the vibration-proof lens 13 both in the X and the Y axis reach the front of the predetermined value Lstop of the center position LS,  
20 and the process proceeds to step S918 when both axes reach a predetermined value. At step S918, the centering timer interrupt process of the vibration-proof lens 13 is disabled. This renders the motors 4 and 5 into a short-brake state to stop the vibration-  
25 proof lens 13 in both directions and the process proceeds to step S919 to end the vibration-proof lens centering process.



[0065]

Figure 15 is a flow chart illustrating one embodiment of the vibration-proof lens centering timer interrupt process at step S903 in Figure 12.

- 5 Practically, two vibration-proof lens centering timer interrupt processes for the X and the Y axis are performed, but both processes are the same, so that the process only on the X axis side is described and the process on the Y axis side is omitted. The process is
- 10 repeated at a predetermined time interval (for example, 1 ms) by permitting the vibration-proof lens centering timer interrupt process at step S903. The vibration-proof lens position  $LR(X)$  set by the preceding vibration-proof lens centering timer interrupt process
- 15 is set to  $LR'(X)$  at step S1201. The position of the X axis of the vibration-proof lens 13 detected by the X axis lens position detecting circuit 6 is set to  $LR(X)$  at step S1202. At step S1203,  $LR'(X)$  is subtracted from  $LR(X)$  to calculate variation in position of the
- 20 vibration-proof lens 13 during a predetermined time period, i.e., the velocity  $VR(X)$  of the vibration-proof lens 13 in the X axis direction.

[0066]

- At step S1204, a determination is made as to
- 25 whether the vibration-proof lens velocity  $VR(X)$  in the X axis direction is greater than  $VR_{max}(X)$ . If the velocity is greater, the process proceeds to step S1205

to set VR(X) to VRmax(X) and proceeds to step S1206.  
On the other hand, if not, the process proceeds to step  
S1206. At step S1206, a determination is made as to  
whether the vibration-proof lens velocity VR(X) in the  
5 X axis direction is smaller than VRmin(Y). If the  
velocity is smaller, the process proceeds to step S1207  
to set VR(X) to VRmin(X) and proceeds to step S1208.  
On the other hand, if not, the process proceeds to step  
S1208. The processes at steps S1204 to S1207 detect  
10 the maximum value VRmax(X) and the minimum value  
VRmin(X) of the vibration-proof lens velocity VR(X) in  
the X axis direction.

[0067]

At step S1208, whether the vibration-proof lens  
15 position LR(X) in the X axis direction is driven to the  
front of the predetermined value Lstop of the center  
position LS is determined based on whether LR(X) +  
Lstop are equal to or greater than LS. If LR(X) is  
driven to the position, the process proceeds to step  
20 S1209 to set the X axis vibration-proof lens stop FLG.  
At step S1210, the motor 4 is rendered a short-brake  
state and the process proceeds to step S1214 to end the  
vibration-proof lens centering timer interrupt process.  
On the other hand, if LR(X) is not yet driven to the  
25 position, the process proceeds to step S1211. At step  
S1211, the target velocity VC(X) of the vibration-proof  
lens in the X axis direction is calculated by the

following equation (Expression 47). At step S1212, a drive duty is calculated by the following equation (Expression 48):

(Expression 47)  $VC(X) = K10 \times \{LS - LR(X)\} + Voffset$

5 (Expression 48) Centering drive duty =  $K1 \times VC(X) + K2 \times \{VC(X) - VR(X)\} \pm Doffset$ .

[0068]

The equation (Expression 47) represents that the target velocity  $VC(X)$  of the vibration-proof lens in the X axis direction is obtained by adding a predetermined velocity  $Voffset$  to a velocity according to a difference between the vibration-proof lens position  $LR(X)$  in the X axis direction detected by the X lens position detecting circuit 6 and the center position  $LS$ . The drive duty driving the motor 4 is represented by the equation (Expression 48) until the vibration-proof lens position  $LR(X)$  in the X axis direction reaches the front of the predetermined value  $Lstop$  of the center position  $LS$  and after that the motor 4 is rendered into a short brake state. The equation (Expression 48) obtains the drive duty such that a duty in which the target velocity  $VC(X)$  of the vibration-proof lens in the X axis direction is multiplied by a predetermined coefficient  $K1$  is added to a duty calculated by multiplying a difference between the  $VC(X)$  and the vibration-proof lens velocity  $VR(X)$  in the X axis direction by a predetermined

coefficient  $K_2$  and that if the value is positive, Doffset is further added and if the value is negative, Doffset is subtracted. Thereby, the vibration-proof lens 13 is controlled by the vibration-proof lens 5 target velocity  $VC(X)$  substantially set in the X axis direction.

[0069]

At step S1213, the motor 4 is driven at the calculated drive duty to drive the vibration-proof lens 13 in the direction of the center position LS of the X axis and the process proceeds to step S1214 to end the process.

[0070]

The centering control of the vibration-proof lens 13 is described below. Figure 6 is a chart describing the centering control in the X axis direction of the vibration-proof lens 13. In Figure 6, the centering drive of the vibration-proof lens 13 starts at D1 and an attempt is made to control the vibration-proof lens 13 to the set target velocity  $VC(X)$  of the vibration-proof lens. The vibration-proof lens velocity  $VR(X)$  in the X axis direction gradually increases based on a relationship of time constant of the vibration-proof control system including the motor 4 and the vibration-proof lens shifting mechanism and reaches the maximum value at D2. Between D2 and D3 being the front of Lstop of the center position LS, the target velocity

VC(X) is set by a linear line calculated from the equation (Expression 47). The vibration-proof lens 13 is controlled in velocity along the linear line. The vibration-proof lens velocity VR(X) gradually decreases  
5 as it gets close to the center position LS. At D3, the motor 4 is rendered into a short brake state and the vibration-proof lens 13 finally stops at D4 in the vicinity of the center position LS.

[0071]

10 Thus, the execution of the vibration-proof lens centering process drives the vibration-proof lens 13 to the vicinity of the target center position LS, detects the maximum value of the vibration-proof lens velocity in the X axis direction during the drive and stores it  
15 as VRmax(X). The maximum value VRmax(X) varies according to mobility of the vibration-proof lens shifting mechanism. If the mechanism has a failure for some reason, the maximum value VRmax(X) decreases to set the X axis vibration-proof lens motion abnormality  
20 FLG. If the X axis lens position detecting circuit 6 has an abnormality to calculate an impossible vibration-proof lens velocity VR(X) at the time of the centering control and the velocity is a negative value, for example, the value is stored in VRmin(X) and at the  
25 same time the X axis vibration-proof lens position detection abnormality FLG is set.

[0072]

The Y axis vibration-proof lens centering timer interrupt process is performed similarly with the above process in the X axis direction. That is to say, the maximum value of the vibration-proof lens velocity in the Y axis direction at that point is stored in VRmax(Y) and if each abnormality is found, each abnormality FLG is set (such as the Y axis vibration-proof lens motion abnormality FLG and the Y axis vibration-proof lens position detection abnormality FLG). If both axes do not reach the center position LS after the control has been continued for a predetermined period of time, the vibration-proof lens time-out abnormality FLG is set.

[0073]

Figure 13 is a flow chart illustrating one embodiment of the vibration-proof-control starting process at step S709 in Figure 10. This is a process in which the maximum and the minimum value of the X and the Y axis vibration-proof lens target position, the maximum and the minimum value of the vibration-proof lens position and control error are detected to move the vibration-proof lens 13 to each direction according to the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9, starting the vibration-proof control process for suppressing hand shake on an image surface. The process proceeds to step S1000 from step S709 to start the present process.

At step S1001, the current vibration-proof lens positions are detected from the outputs of the X and the Y axis lens position detecting circuit 6 and 7 and set to the vibration-proof lens target position LC(X) and LC(Y) of the X and the Y axis respectively. At step S1002, the current vibration-proof lens positions detected by the outputs of the X and the Y axis lens position detecting circuit 6 and 7 are set to the maximum values LCmax(X) and LCmax(Y) and the minimum values LCmin(X) and LCmin(Y) of the vibration-proof lens target position LC(X) and LC(Y) of the X and the Y axis respectively.

[0074]

At step S1003, the current vibration-proof lens positions detected by the outputs of the X and the Y axis lens position detecting circuit 6 and 7 are set to the maximum values LRmax(X) and LRmax(Y) and the minimum values LRmin(X) and LRmin(Y) of the vibration-proof lens position of the X and the Y axis respectively. At step S1004, the maximum values  $\Delta L_{max}(X)$  and  $\Delta L_{max}(Y)$  and the minimum values  $\Delta L_{min}(X)$  and  $\Delta L_{min}(Y)$  of the vibration-proof lens position error of the X and the Y axis are cleared. At step S1005, the vibration-proof-control timer interrupt process (Figure 16) is permitted to start the vibration-proof control. At step 1006, the present vibration-proof-control starting process is ended.

[0075]

Figure 16 is a flow chart illustrating one embodiment of the vibration-proof-control timer interrupt process in which the vibration-proof-control timer interrupt process is permitted by the vibration-proof-control starting process at step S1005 in Figure 13 to perform the process at a predetermined time interval. The process starts at step S1300. Practically, two vibration-proof-control timer interrupt processes for the X and the Y axis are performed, but both processes are the same, so that the process only on the X axis side is described and the process on the Y axis side is omitted. The process is repeated at a predetermined time interval (for example, 1 ms). At step S1301, the vibration-proof lens position  $LR(X)$  set by the preceding vibration-proof-control timer interrupt process is set to  $LR'(X)$ . At step S1302, the position of the X axis of the vibration-proof lens 13 detected by the X axis lens position detecting circuit 6 is set to  $LR(X)$ .

[0076]

At step S1303, the maximum and the minimum values of the vibration-proof lens position are detected. Figure 17 is a flow chart illustrating one embodiment of the process for detecting the maximum and the minimum values of the vibration-proof lens positions. The process proceeds to step S1400 in Figure 17 from



step S1303. At step S1401, a determination is made as to whether the X axis vibration-proof lens position  $LR(X)$  is larger than  $LR_{max}(X)$ . If it is larger, the process proceeds to step S1402 to set  $LR(X)$  to  $LR_{max}(X)$  and the process proceeds to step S1403. If not, the process proceeds to step S1403. At step S1403, a determination is made as to whether the X axis vibration-proof lens position  $LR(X)$  is smaller than  $LR_{min}(X)$ . If it is smaller, the process proceeds to step S1404 to set  $LR(X)$  to  $LR_{min}(X)$  and the process proceeds to step S1405. If not, the process proceeds to step S1405. The process is ended at steps 1405. The above process detects the maximum and the minimum values of the vibration-proof lens position  $LR(X)$  in the X axis direction as  $LR_{max}(X)$  and  $LR_{min}(X)$  respectively.

[0077]

The process proceeds to step S1304 in Figure 16 from step S1405. At step S1304,  $LR'(X)$  is subtracted from  $LR(X)$  to calculate variation in position of the vibration-proof lens 13 in the X axis direction during a predetermined time period, i.e., the velocity  $VR(X)$  of the vibration-proof lens 13 in the X axis direction. At step S1305, the output of the yaw angular velocity detecting circuit 8 is A/D converted and the value is set as "u." At step S1306, "u" is multiplied by a gain adjustment value A1 to set it as "U," calculating a

gain-adjusted angle velocity in the yaw direction. At step S1307, as represented by the equation (Expression 23), the gain-adjusted angular velocity value  $V$  in the other pitch direction multiplied by the angle

- 5 displacement adjustment value  $\Delta\alpha (= \sin \alpha)$  is added to "U" to calculate the output  $X$  in which an angle displacement is corrected.

[0078]

- Where, "V" is a gain-adjusted angle velocity value  
 10 calculated in the vibration-proof-control timer interrupt process in the Y axis being the other axis. Strictly speaking, the present vibration-proof-control timer interrupt processes in both the X and the Y axis cannot be performed at the same time, so that sampling  
 15 timings at which the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 are A/D converted are different from each other. However, the amount of "V" which varies during displacement between the timings is very small and negligible.

20 [0079]

- At step S1308, the output  $X$  calculated at step S1307 is multiplied by the angular-velocity to vibration-proof lens target-velocity converting coefficient  $B$  to calculate the X axis vibration-proof  
 25 lens target velocity  $VC(X)$ . At step S1309, the target velocity  $VC(X)$  is added to the X axis vibration-proof lens target position  $LC(X)$  to set  $LC(X)$ . The target

velocity  $VC(X)$  is accumulated at a predetermined time interval to enable the vibration-proof lens target position  $LC(X)$  to be calculated. Since the target position  $LC(X)$  is set at the timing at step S1001 in Figure 13, the vibration-proof lens target velocity  $VC(X)$  is accumulated while the vibration-proof-control timer interrupt process is permitted with the timing as an initial value to continue calculating the vibration-proof lens target position  $LC(X)$ .

10 [0080]

At step S1310, the maximum and the minimum values of the vibration-proof lens target position are detected. Figure 18 is a flow chart illustrating one embodiment of a process for detecting the maximum and the minimum values of the vibration-proof lens target position. The process proceeds to step S1500 in Figure 18 from step S1310. At step S1501, a determination is made as to whether the X axis vibration-proof lens target position  $LC(X)$  is greater than  $LCmax(X)$ . If it is greater, the process proceeds to step S1502 to set  $LC(X)$  to  $LCmax(X)$ . At step S1503, the sign of the vibration-proof lens target velocity  $LC(Y)$  of the Y axis being the other axis is held and the process proceeds to step S1504. At step S1501, if it is not greater, the process proceeds to step S1504.

[0081]

At step S1504, a determination is made as to

whether the X axis vibration-proof lens target position  $LC(X)$  is smaller than  $LCmin(X)$ . If it is smaller, the process proceeds to step S1505 to set  $LC(X)$  to  $LCmin(X)$  and proceeds to step S1506. If it is not smaller, the  
 5 process proceeds to step S1506. The process ends at step S1506. The process detects the maximum and the minimum values of the vibration-proof lens target position  $LC(X)$  in the X axis direction in  $LCmax(X)$  and  $LCmin(X)$  respectively and the sign of the vibration-  
 10 proof lens target position  $LC(Y)$  in the other axis at the time of detecting the maximum value can be obtained.  
 [0082]

The process proceeds to step S1311 in Figure 16 from step S1506. At step S1311, the vibration-proof  
 15 lens position  $LR(X)$  is subtracted from the X axis vibration-proof lens target position  $LC(X)$  to calculate the vibration-proof lens position error  $\Delta L(X)$ . The process proceeds to step S1312 to detect the maximum and the minimum values of the vibration-proof lens  
 20 position error. Figure 19 is a flow chart illustrating one embodiment of a process for detecting the maximum and the minimum values of the vibration-proof lens position error. The process proceeds to step S1600 in Figure 19 from step S1312. At step S1601, a  
 25 determination is made as to whether the X axis vibration-proof lens position error  $\Delta L(X)$  is greater than  $\Delta Lmax(X)$ . If it is greater, the process proceeds

to step S1602 to set  $\Delta L(X)$  to  $\Delta L_{\max}(X)$  and proceeds to step S1603. If it is not greater, the process proceeds to step S1603. At step S1603, a determination is made as to whether the X axis vibration-proof lens position error  $\Delta L(X)$  is smaller than  $\Delta L_{\min}(X)$ . If it is smaller,  $\Delta L(X)$  is set to  $\Delta L_{\min}(X)$  at step S1604 and proceeds to step S1605. If it is not smaller, the process proceeds to step S1605 to end the process. The process detects the maximum and the minimum values of the vibration-proof lens position error  $\Delta L(X)$  in the X axis direction in  $\Delta L_{\max}(X)$  and  $\Delta L_{\min}(X)$  respectively.

[0083]

The process proceeds to step S1313 in Figure 16 from step S1605. At step S1313, a drive duty at which the motor 4 is driven under the vibration-proof control is calculated. The drive duty is calculated from, for example, the equation (Expression 48) used at the time of the centering control. At step S1314, a determination is made as to whether a vibration-proof adjustment is performed. If no, the process proceeds to step S1315 to drive the motor 4 at the drive duty calculated at step S1313. If the vibration-proof adjustment is performed, the process proceeds to step S1316 (without driving the motor 4) to end the present vibration-proof-control timer interrupt process.

[0084]

(2) Process on the communication tool side

Referring to Figures 7 to 9, there are described the total inspection of the vibration-proof lens shifting mechanism, the gain adjustment and the detection angle displacement adjustment of the yaw and the pitch angular velocity detecting circuit 8 and 9 and the total inspection of a vibration-proof controllability which are performed on the communication tool side. The start of the present process at step S601 sets the camera to the communication mode by a known method. This setting starts the communication-mode process of the camera executed by the CPU 1 illustrated in Figure 10. The following processes from steps S602 to S607 inspect the vibration-proof lens shifting mechanism. At step S602, a vibration-proof lens resetting instruction is issued to the CPU 1. The CPU 1 of the camera drives the vibration-proof lens 13 to a predetermined resetting position at step S704 in Figure 10 in response to the instruction. At step S603, a vibration-proof lens centering instruction is issued to drive the vibration-proof lens 13 to the center position LS. At step S604, the CPU 1 reads the maximum values VRmax(X) and VRmax(Y) of the vibration-proof lens velocities of the X and the Y axis detected at the vibration-proof lens centering at step S603 and centering abnormality data (such as a vibration-proof lens centering time-out abnormality FLG, an X and a Y axis vibration-proof lens

motion abnormality FLG and an X and a Y axis vibration-proof lens position detection abnormality FLG) using the data read instruction.

[0085]

5           At step S605, a determination is made as to whether the maximum value VRmax(X) is equal to or greater than a predetermined value. If it is equal to or greater than the predetermined value, the process proceeds to step S606. If not, the process proceeds to  
10 step S646 (refer to Figure 9) and determines that the mechanism is defective. The process proceeds to step S647. At step S606, a determination is made as to whether the maximum value VRmax(Y) is equal to or greater than a predetermined value. If it is equal to  
15 or greater than the predetermined value, the process proceeds to step S607. If not, the process proceeds to step S646, similarly to the above, and determines that the mechanism is defective. At step S607, a  
20 determination is made by the centering abnormality data as to whether the centering is abnormal. If the centering is not abnormal, in other words, if any one of the abnormal FLGs is not set, the process proceeds to step S608. If at least one of the abnormal FLGs is set, similarly to the above, the process proceeds to  
25 step S646 and determines that the mechanism is defective.

[0086]

Thus, centering the vibration-proof lens 13 and detecting the maximum value of the vibration-proof lens velocity during the centering control or each abnormality through the above processes at steps S603 to S607 and S646 enable the vibration-proof lens shifting mechanism to be determined defective if the motion of the vibration-proof lens 13 is abnormal in the X and the Y axis direction or the output of the X and the Y axis lens position detecting circuit 6 and 7 is abnormal for some reason.

[0087]

The processes at steps S608 to S624 perform the gain adjustment and the detection angle displacement adjustment of the yaw and the pitch angular velocity detecting circuit 8 and 9. The gain adjustment values A1 and A2 held in the CPU 1 at the timing at step S608 are the initial value A0 set at step S700 in Figure 10. The angle displacement adjustment value  $\Delta\alpha$  and  $\Delta\beta$  are the initial value 0 written at step S702 in Figure 10.

At step S608, the application of vibration in the X axis direction is started. This vibrates the shaking table 18. The vibration is sinusoidal and has a predetermined angular amplitude in the X axis direction. At step S609, the vibration-proof adjustment starting instruction is issued to the CPU 1. The CPU 1 executes the vibration-proof-control starting process according to the instruction at step S609 and based on step S709



in Figure 10. The vibration-proof-control timer interrupt process illustrating in Figure 16 continues detecting the maximum values LCmax(X) and LCmax(Y) and the minimum values LCmin(X) and LCmin (Y) of the vibration-proof lens target positions and signs of LC(Y) and LC(X) at the time of detecting LCmax(X) and LCmax(Y) respectively. Since the execution is determined as the vibration-proof adjustment at step S1314 in Figure 16, the motor is not driven, so that the vibration-proof lens 13 is not driven either.

[0088]

At step S610, the process waits for a predetermined period of time. At step S611, the vibration-proof adjustment ending instruction is issued to the CPU 1. The CPU 1 disables the vibration-proof-control timer interrupt process at step S712 in Figure 10 to end the vibration-proof control. At step S612, vibration in the X axis direction by the shaking table 18 is ended. The wait at step 610 is a time during which each of the maximum and the minimum value of the vibration-proof lens target position can be detected at least once at steps S609 to S611. At step S613, using the data read instruction, LCmax(X), LCmax(Y), LCmin(X) and LCmin (Y) and the signs of the LC(Y) and LC(X) each at the time of detecting LCmax(X) and LCmax(Y) detected by the CPU 1 are read from the CPU 1. At step S614, the total amplitudes "a," "b" and "c" of the vibration-

proof lens target positions of the X and the Y axis are calculated using the equations (Expression 37), (Expression 38) and (Expression 39).

[0089]

5           The process proceeds to step S615 in Figure 8. At step S615, the shaking table 18 is vibrated. The vibration is sinusoidal and has a predetermined angular amplitude in the Y axis direction. At step S616, the vibration-proof adjustment starting instruction is  
10   issued to the CPU 1. The CPU 1 executes the vibration-proof-control starting process according to the instruction at step S616 and based on step S709 in Figure 10. The vibration-proof-control timer interrupt process illustrating in Figure 16 continues detecting  
15   the maximum values  $LC_{max}(X)$  and  $LC_{max}(Y)$  and the minimum values  $LC_{min}(X)$  and  $LC_{min}(Y)$  of the vibration-proof lens target positions and signs of  $LC(Y)$  and  $LC(X)$  at the time of detecting  $LC_{max}(X)$  and  $LC_{max}(Y)$  respectively. Since the execution is not determined as  
20   the vibration-proof adjustment at step S1314 in Figure 16, the motor is not driven, so that the vibration-proof lens 13 is not driven either.

[0090]

          At step S617, the process waits for a  
25   predetermined period of time. At step S618, the vibration-proof adjustment ending instruction is issued to the CPU 1. The CPU 1 disables the vibration-proof-

control timer interrupt process at step S712 in Figure 10 to end the vibration-proof control. At step S619, vibration in the Y axis direction by the shaking table 18 is ended. The wait at step 617 is a time during

5 which each of the maximum and the minimum value of the vibration-proof lens target position can be detected at least once at steps S616 to S618. At step S620, using the data read instruction, LCmax(X), LCmax(Y), LCmin(X) and LCmin (Y) and the signs of the respective LC(Y) and

10 LC(X) at the time of detecting LCmax(X) and LCmax(Y) detected by the CPU 1 are read from the CPU 1. At step S621, the total amplitudes "d," "e" and "f" of the vibration-proof lens target positions of the X and the Y axis are calculated using the equations (Expression

15 40), (Expression 41) and (Expression 42).

[0091]

At step S622, the gain adjustment values A1 and A2 of outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 are calculated using the

20 equations (Expression 43) and (Expression 44). At step S623, the detection angle displacement adjustment values  $\Delta\alpha$  and  $\Delta\beta$  of the yaw and the pitch angular velocity detecting circuit 8 and 9 are calculated by the equations (Expression 45) and (Expression 46). At

25 step S624, the E2PROM write instruction is issued. The gain adjustment values A1 and A2 and the detection angle displacement adjustment values  $\Delta\alpha$  and  $\Delta\beta$  are

written in the E2PROM. The above processes at steps S608 to S624 allow performing the gain adjustment and the detection angle displacement adjustment of the yaw and the pitch angular velocity detecting circuit 8 and

5 9.

[0092]

The processes at step S625 and the following steps perform the total inspection of the vibration-proof controllability. The gain adjustment values A1 and A2 held in the CPU 1 at the timing at step S625 are the initial value A0 set at step S700 in Figure 10. The angle displacement adjustment value  $\Delta\alpha$  and  $\Delta\beta$  are the initial value 0 written at step S702 in Figure 10. At step S625, the data write instruction is issued. The

15 values of 1/m of A1 and A2 calculated at step S622 are written in the gain adjustment values A1 and A2 in the CPU 1 and  $\Delta\alpha$  and  $\Delta\beta$  calculated at step S623 are written in the angle displacement adjustment values  $\Delta\alpha$  and  $\Delta\beta$  in the CPU 1. The process proceeds to step S626.

20 [0093]

At step S626, the shaking table 18 is vibrated. The vibration is sinusoidal and has a predetermined angular amplitude in the X axis direction. At step S627, the vibration-proof-control starting instruction

25 is issued to the CPU 1. The CPU 1 executes the vibration-proof-control starting process according to the instruction at step S627 and based on step S709 in

Figure 10. The vibration-proof-control timer interrupt process illustrating in Figure 16 continues detecting the maximum values  $LR_{max}(X)$  and  $LR_{max}(Y)$  and the minimum values  $LR_{min}(X)$  and  $LR_{min}(Y)$  of the vibration-proof lens positions and the maximum values  $\Delta L_{max}(X)$  and  $\Delta L_{max}(Y)$  and the minimum values  $\Delta L_{min}(X)$  and  $\Delta L_{min}(Y)$  of the vibration-proof lens control errors. The execution is determined as the vibration-proof adjustment at step S1314 in Figure 16, so that the motor is driven to control the vibration-proof lens 13 as is not the case with the gain adjustment and the detection angle displacement adjustment.

[0094]

At step S628, the process waits for a predetermined period of time. At step S629, the vibration-proof control ending instruction is issued. The CPU 1 disables the vibration-proof-control timer interrupt process at step S712 in Figure 10 to end the vibration-proof control. At step S630, vibration is ended by the shaking table 18. The wait at step 628 is a time in which a period of vibration applied by the shaking table 18 is equal to or longer than one period at steps S627 to S629. The reason the wait is set to the above time is that a check is made as to whether controllability is good in all timings of one period of the sinusoidal wave, while the vibration proof lens 13 is sinusoidally controlled. The process proceeds to

step S631 in Figure 9 from step S630. At step S631, the maximum value  $LR_{max}(X)$  and the minimum value  $LR_{min}(X)$  of the X axis vibration-proof lens position and the maximum value  $\Delta L_{max}(X)$  and the minimum value  $\Delta L_{min}(X)$  of the X axis vibration-proof lens position error detected by the CPU 1 are read from the CPU 1 using the data read instruction. At step S632, an amplitude "g" in the X axis direction of the vibration-proof lens 13 actually controlled is calculated by the following equation (Expression 49):

$$(Expression\ 49)\ g = LR_{max}(X) - LR_{min}(X).$$

[0095]

At step S633, a determination is made as to whether the absolute value of a value in which the actual total amplitude "g" in the X axis direction of the vibration proof lens 13 obtained at step S632 is subtracted from the value of  $1/m$  of the total amplitude  $L01$  in the X axis direction of the vibration proof lens 13 desired to be obtained after gain adjustment is equal to or less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S634. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647.

[0096]

Since the vibration-proof gain adjustment value  $A_1$  in the yaw direction obtained at step S622 is multiplied by  $1/m$  at step S625, if the amplitude "g" of the vibration proof lens 13 actually obtained is equal to  $1/m$  of  $L_{01}$ , the gain adjustment can be considered accurate and the vibration-proof controllability can be considered good. However, if the gain adjustment is not accurately performed for some reason or if the total amplitude of the vibration proof lens 13 actually controlled is not theoretically obtained because the vibration-proof lens shifting mechanism is out of order, a defect can be checked based on determination at step S633.

[0097]

At step S634, a determination is made as to whether the absolute value of the maximum value  $\Delta L_{\max}(X)$  of a vibration-proof lens position error in the X axis direction is equal to or less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S635. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647. At step S635, a determination is made as to whether the absolute value of the minimum value  $\Delta L_{\min}(X)$  of a vibration-proof lens position error in the X axis direction is equal to or

less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S636. If not, the process proceeds to step S646, determines that the vibration-  
5 proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647.  
[0098]

The processes at steps S634 and S635 check controllability in the X axis direction of the  
10 vibration-proof lens 13. In the above vibration-proof-control timer interrupt process, the vibration-proof lens position error  $\Delta L(X)$  being the difference between the vibration-proof lens target position  $LC(X)$  and the vibration-proof lens position  $LR(X)$  actually controlled  
15 is calculated and the maximum value  $\Delta L_{max}(X)$  and the minimum value  $\Delta L_{min}(X)$  of the vibration-proof lens position error are detected. At steps S634 and S635, if the absolute values of  $\Delta L_{max}(X)$  and  $\Delta L_{min}(X)$  are small, the controllability can be determined as good,  
20 or if the absolute values are great, the controllability can be determined as unacceptable.  
[0099]

The processes at step S636 and the following steps check the vibration-proof controllability in the Y axis  
25 direction. At step S636, the shaking table 18 is vibrated. The vibration is sinusoidal and has a predetermined angular amplitude in the Y axis direction.



At step S637, the vibration-proof-control starting instruction is issued to the CPU 1. The CPU 1 executes the vibration-proof-control starting process according to the instruction at step S637 and based on step S709 in Figure 10. The vibration-proof-control timer interrupt process illustrating in Figure 16 continues detecting the maximum values  $LR_{max}(X)$  and  $LR_{max}(Y)$  and the minimum values  $LR_{min}(X)$  and  $LR_{min}(Y)$  of the vibration-proof lens positions and the maximum values  $\Delta L_{max}(X)$  and  $\Delta L_{max}(Y)$  and the minimum values  $\Delta L_{min}(X)$  and  $\Delta L_{min}(Y)$  of the vibration-proof lens control errors. The execution is determined as the vibration-proof adjustment at step S1314 in Figure 16, so that the motor is driven to control the vibration-proof lens

13.

[0100]

At step S638, the process waits for a predetermined period of time. At step S639, the vibration-proof control ending instruction is issued.

The CPU 1 disables the vibration-proof-control timer interrupt process at step S712 in Figure 10 to end the vibration-proof control. At step S640, vibration is ended by the shaking table 18. The wait at step 638 is a time in which a period of vibration applied by the shaking table 18 is equal to or longer than one period at steps S637 to S639. The reason to do so is the same as in the wait at step S628. At step S641, the maximum

value  $LR_{max}(Y)$  and the minimum value  $LR_{min}(Y)$  of the Y axis vibration-proof lens position and the maximum value  $\Delta L_{max}(Y)$  and the minimum value  $\Delta L_{min}(Y)$  of the Y axis vibration-proof lens position error detected by the CPU 1 are read from the CPU 1 using the data read instruction. At step S642, an amplitude "h" in the Y axis direction of the vibration-proof lens 13 actually controlled is calculated by the following equation (Expression 50):

10 (Expression 50)  $h = LR_{max}(Y) - LR_{min}(Y)$ .  
 [0101]

At step S643, a determination is made as to whether the absolute value of a value in which the actual total amplitude "h" in the Y axis direction of the vibration proof lens 13 obtained at step S642 is subtracted from the value of  $1/m$  of the total amplitude  $L02$  in the Y axis direction of the vibration proof lens 13 desired to be obtained after gain adjustment is equal to or less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S644. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647. The reason the above determination is made at step S643 is the same as that at step S633.

25 [0102]

At step S644, a determination is made as to whether the absolute value of the maximum value  $\Delta L_{\max}(Y)$  of a vibration-proof lens position error in the Y axis direction is equal to or less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S645. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647. At step S645, a determination is made as to whether the absolute value of the minimum value  $\Delta L_{\min}(Y)$  of a vibration-proof lens position error in the Y axis direction is equal to or less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S647. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647.

[0103]

The processes at steps S644 and S645 check controllability in the Y axis direction of the vibration-proof lens 13. In the above the vibration-proof-control timer interrupt process, the vibration-proof lens position error  $\Delta L(Y)$  being a difference between the vibration-proof lens target position  $LC(Y)$  and the vibration-proof lens position  $LR(Y)$  actually

controlled is calculated and the maximum value  $\Delta L_{\max}(Y)$  and the minimum value  $\Delta L_{\min}(Y)$  of the vibration-proof lens position error are detected. At steps S644 and S645, if the absolute values of  $\Delta L_{\max}(Y)$  and  $\Delta L_{\min}(Y)$  are small, the controllability can be determined as good, or if the absolute values are great, the controllability can be determined as unacceptable.

[0104]

At step S647, the vibration-proof lens resetting instruction is issued to the CPU 1. The CPU 1 drives the vibration proof lens 13 to a predetermined position based on step S704 in Figure 10. At step S648, the communication mode release instruction is issued to the CPU 1 to release the camera from the communication mode.

At step S649, the communication-tool adjustment process is ended.

[0105]

The reason the gain adjustment values A1 and A2 are set to 1/m respectively at step S625 is due to the following. The outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 are typically increased at the time of the gain adjustment and the angle displacement adjustment to gain the dynamic range, thereby improving an accuracy in adjustment. Therefore, the vibration angle of the shaking table 18 is also increased. In this case, when the above vibration-proof controllability is checked

with the vibration angle remained unchanged, the vibration proof lens 13 needs controlling beyond the driving capacity of vibration-proof lens shifting mechanism or the shift range of the vibration proof lens 13 can be exceeded.

[0106]

The angle range or the angle velocity of hand shake of a user who uses an ordinary camera is smaller than an angle at which the gain adjustment and angle displacement adjustment are performed. Accordingly, the vibration angle of the shaking table 18 may be decreased only at the time of checking the vibration-proof controllability to meet the above. However, it is not easy to mechanically set the vibration angle of the shaking table 18 to two steps. For this reason, the value of "m" is set so as to cover the angle range or the angle velocity range generated when a user uses an ordinary camera, checking a realistic vibration-proof controllability. The value of "m" is varied to check such a realistic vibration-proof controllability, enabling a more accurate check. On the other hand, it is not easy to mechanically set the vibration angle of the shaking table 18 to a plurality of steps.

[0107]

A process in the case where the camera is used by a user is described below. Figure 20 is a flow chart illustrating one embodiment of the half-depression

process for the camera according to the present invention. The process illustrated in Figure 20 is performed when the half-depression SW 16 is turned on. At step S1700, the process starts. At step S1701, the gain adjustment values A1 and A2 are read from the E2PROM. At step S1702, the angle displacement adjustment values  $\Delta\alpha$  and  $\Delta\beta$  are read from the E2PROM. At step S1703, a determination is made as to whether the full-depression SW 17 is turned on. If the SW 17 is turned on, the process proceeds to step S1706. If the SW 17 is turned off, the process proceeds to step S1704 to determine whether the half-depression SW 16 is turned on. If the SW 16 is turned on, the process returns to step S1703. If the SW 16 is turned off, the process proceeds to step S1705 to end the process.

[0108]

At step S1706, the foregoing vibration-proof lens centering process (Figure 12) is performed to drive the vibration proof lens 13 to the center positions in the X and the Y axis direction. At step S1707, the vibration-proof-control starting process (Figure 13) is performed. The vibration-proof-control timer interrupt process (Figure 16) is permitted to start the vibration-proof control. At step S1708, a shutter is opened and closed to perform an exposure process. After the exposure process is ended, the vibration-proof-control timer interrupt is disabled at step S1709

to end the vibration-proof-control. In addition, the motors 4 and 5 are rendered into a short brake for a predetermined period of time to end the vibration proof lens 13. At step S1710, the vibration-proof lens  
5 resetting process (Figure 11) drives the vibration proof lens 13 to a reset position. The process proceeds to step S1711 to end the present half-depression process.

[0109]

10 In the vibration-proof-control timer interrupt between the start of the vibration-proof-control at step S1707 and the end of the vibration-proof-control at step S1709 including the exposure at step S1708, the vibration-proof-control is performed by the output in  
15 which the gain adjustment values A1 and A2 and the angle displacement adjustment values  $\Delta\alpha$  and  $\Delta\beta$  are read from the E2PROM at steps S1701 and S1702, the dispersion in the gains is corrected at step S1306 and the angle displacement is corrected at step S1307.  
20 Thereby, an accurate vibration-proof control is performed.

[0110]

One embodiment of the present invention has been described above. The present invention can be  
25 implemented in various forms without limiting to the above embodiment and deviating from the gist of the present invention. For example, although, in the above

embodiment, the amount of angle displacement is electrically detected to write the adjustment value thereof into the E2PROM of the camera to electrically correct the angle displacement, the amount of angle displacement is detected by this method and the angle displacement may be adjusted by mechanically adjusting an angular velocity sensor or an angular velocity detecting circuit. Although, in the above description, the speed of the motors 4 and 5 is controlled by the PWM control method, the control method of the motors 4 and 5 are not limited to the above. In the above description of the present embodiment, as a method of varying the optical axis of a photographing optical system, there is used a method of shifting a part (the vibration proof lens 13) of the photographing optical system, however, aside from the above, a vari-angle prism may be used or other actuators such as a voice coil may be used instead of the motor.

[0111]

20 In the embodiment of the present embodiment, although the communication-tool side inspects and adjusts the shake correction function of the camera, in addition to the above, for example, the inspection and the adjustment function are provided on the CPU 1 of the camera to enable the camera to be self diagnosed.

[0112]

[Advantages of the Invention]



According to the present invention, since a first and second adjustment values of angle displacements between a first and second directions in which the optical axis of a photographing optical system varies and the directions of the angle velocities detected by a first and second angular velocity detecting units are stored to correct errors of outputs of the first and second angular velocity detecting units based on the first and second adjustment values of angle displacements, a more accurate shake correction can be performed independently of the influence of error in attachment of the first and second angular velocity detecting units at the time of assembly of the camera. In the case where the angle displacement is adjusted based on the integral value or the accumulated value of outputs of the first and second angular velocity detecting circuits, accuracy in adjustment can be prevented from lowering due to variation in the frequency of a sinusoidal vibration applied at the time of adjusting the angle displacement or an unwanted high-frequency noise superposed on the sinusoidal vibration, enabling more accurate adjustment of the angle displacement.

[Brief Description of the Drawings]

[Figure 1]

Figure 1 is a schematic diagram illustrating the configuration of portions of a camera, a communication

tool and a shaking table.

[Figure 2]

Figure 2 is a schematic diagram illustrating dispersion in the gains of the yaw and the pitch angular velocity detecting circuit 8 and 9.

[Figure 3]

Figure 3 is a chart describing a angle displacement.

[Figure 4]

Figure 4 is a chart illustrating how the gain and the angle displacement are adjusted according to the present invention.

[Figure 5]

Figure 5 is a chart illustrating how the gain and the angle displacement are adjusted according to the present invention.

[Figure 6]

Figure 6 is a chart describing the centering control in the X axis direction of the vibration-proof lens 13.

[Figure 7]

Figure 7 is a flow chart illustrating one embodiment of a communication adjustment process performed by the communication tool 15.

[Figure 8]

Figure 8 is a flow chart following Figure 7.

[Figure 9]

Figure 9 is a flow chart following Figure 8.

[Figure 10]

Figure 10 is a flow chart illustrating one embodiment of a communication-mode process performed by the CPU 1 of the camera.

[Figure 11]

Figure 11 is a flow chart illustrating one embodiment of a vibration-proof lens resetting process at step S704 in Figure 10.

10 [Figure 12]

Figure 12 is a flow chart illustrating one embodiment of the vibration-proof lens centering process at step S706 in Figure 10.

[Figure 13]

15 Figure 13 is a flow chart illustrating one embodiment of the vibration-proof-control starting process at step S709 in Figure 10.

[Figure 14]

20 Figure 14 is a flow chart illustrating one embodiment of the vibration-proof lens resetting timer interrupt process.

[Figure 15]

25 Figure 15 is a flow chart illustrating one embodiment of the vibration-proof lens centering timer interrupt process.

[Figure 16]

Figure 16 is a flow chart illustrating one

embodiment of the vibration-proof-control timer interrupt process.

[Figure 17]

Figure 17 is a flow chart illustrating one  
5 embodiment of a process for detecting the maximum and the minimum values of the vibration-proof lens positions.

[Figure 18]

Figure 18 is a flow chart illustrating one  
10 embodiment of a process for detecting the maximum and the minimum values of the vibration-proof lens target position.

[Figure 19]

Figure 19 is a flow chart illustrating one  
15 embodiment of a process for detecting the maximum and the minimum values of the vibration-proof lens position error.

[Figure 20]

Figure 20 is a flow chart illustrating one  
20 embodiment of the half-depression process for the camera according to the present invention.

[Description of Symbols]

- 1 CPU
- 2, 3 X and Y axis motor driving circuits
- 25 4, 5 X and Y axis motors
- 6, 7 X and Y axis lens position detecting circuits
- 8, 9 Yaw and pitch angular velocity detecting circuits

- 10 E2PROM
- 11, 12, 13, 14 Photographic lens (13, Vibration proof lens)
- 15 Communication tool
- 5 16 Half depression SW
- 17 Full-depression SW
- 18 Shaking table

Figure 1

	#1	CAMERA SIDE
	#2	COMMUNICATION TOOL SIDE
	#3	SHAKING TABLE SIDE
5	2	X AXIS MOTOR DRIVING CIRCUIT
	3	Y AXIS MOTOR DRIVING CIRCUIT
	6	X AXIS LENS POSITION DETECTING CIRCUIT
	7	Y AXIS LENS POSITION DETECTING CIRCUIT
	8	YAW ANGULAR VELOCITY DETECTING CIRCUIT
10	9	PITCH ANGULAR VELOCITY DETECTING CIRCUIT
	15	COMMUNICATION TOOL
	16	HALF DEPRESSION SW
	17	FULL DEPRESSION SW
	18	SHAKING TABLE
15		

Figure 2

	#1	DIRECTION
	#2	ANGULAR VELOCITY DETECTING CIRCUIT
	#3	ANGULAR VELOCITY SENSOR
20		

Figure 3

	#1	AXIS DRIVE DIRECTION
	#2	SENSOR DETECTION DIRECTION
	#3	APPLIED ANGULAR VELOCITY DIRECTION
25		

Figure 4

#1	AT THE TIME OF APPLYING VIBRATION IN X AXIS
----	---

DIRECTION

Figure 5

#1 AT THE TIME OF APPLYING VIBRATION IN X AXIS

5 DIRECTION

Figure 7

S600 START COMMUNICATION TOOL ADJUSTMENT PROCESS

S601 PLACE CAMERA INTO COMMUNICATION MODE

10 S602 ISSUE VIBRATION-PROOF LENS RESETING

INSTRUCTION

S603 ISSUE VIBRATION-PROOF LENS CENTERING

INSTRUCTION

S604 READ VRmax(X) AND VRmax(Y) AND EACH CENTERING

15 ABNORMALITY DATA FROM CAMERA

S605 IS VRmax(X) EQUAL TO OR GREATER THAN  
PREDETERMINED VALUE?

S606 IS VRmax(Y) EQUAL TO OR GREATER THAN  
PREDETERMINED VALUE?

20 S607 IS CENTERING ABNORMAL?

S608 START APPLYING VIBRATION IN X AXIS DIRECTION

S609 ISSUE VIBRATION-PROOF ADJUSTMENT STARTING  
INSTRUCTION

S610 WAIT FOR PREDETERMINED PERIOD OF TIME

25 S611 ISSUE VIBRATION-PROOF ADJUSTMENT ENDING  
INSTRUCTION

S612 END APPLICATION OF VIBRATION IN X AXIS

DIRECTION

S613 READ LCmax(X), LCmin(X) AND SIGN OF LC(Y) AT  
THE TIME OF DETECTING LCmax(X) FROM CAMERA AND READ  
LCmax(Y), LCmin(Y) AND SIGN OF LC(X) AT THE TIME OF  
5 DETECTING LCmax(Y) FROM CAMERA  
#1 POSITIVE IN SIGN OF LC(Y) AT THE TIME OF  
DETECTING LCmax(X)  
NEGATIVE IN SIGN OF LC(Y) AT THE TIME OF  
DETECTING LCmax(X)

10

Figure 8

S615 START APPLICATION OF VIBRATION IN Y AXIS  
DIRECTION  
S616 ISSUE VIBRATION-PROOF ADJUSTMENT STARTING  
15 INSTRUCTION  
S617 WAIT FOR PREDETERMINED PERIOD OF TIME  
S618 ISSUE VIBRATION-PROOF ADJUSTMENT ENDING  
INSTRUCTION  
S619 END APPLICATION OF VIBRATION IN Y AXIS  
20 DIRECTION  
S620 READ LCmax(X), LCmin(X) AND SIGN OF LC(Y) AT  
THE TIME OF DETECTING LCmax(X) FROM CAMERA AND READ  
LCmax(Y), LCmin(Y) AND SIGN OF LC(X) AT THE TIME OF  
DETECTING LCmax(Y) FROM CAMERA  
25 #1 POSITIVE IN SIGN OF LC(X) AT THE TIME OF  
DETECTING LCmax(Y)  
NEGATIVE IN SIGN OF LC(X) AT THE TIME OF



DETECTING  $L_{Cmax}(Y)$

#2        CALCULATE GAIN ADJUSTMENT VALUE OF ANGULAR  
VELOCITY DETECTING CIRCUIT

#3        CALCULATE DETECTION ANGLE DISPLACEMENT

5        CORRECTION AMOUNT OF ANGULAR VELOCITY DETECTING CIRCUIT

S624     WRITE  $A1$ ,  $A2$ ,  $\Delta\alpha$  AND  $\Delta\beta$  IN E2PROM OF CAMERA

S625     WRITE  $A1/m$ ,  $A2/m$ ,  $\Delta\alpha$  AND  $\Delta\beta$  IN PREDETERMINED  
DATA OF CPU 1

S626     START APPLYING VIBRATION IN X AXIS DIRECTION

10    S627     ISSUE VIBRATION-PROOF CONTROL STARTING  
INSTRUCTION

S628     WAIT FOR PREDETERMINED PERIOD OF TIME

S629     ISSUE VIBRATION-PROOF CONTROL ENDING  
INSTRUCTION

15    S630     END APPLICATION OF VIBRATION IN X AXIS  
DIRECTION

## Figure 9

S631     READ  $LR_{max}(X)$ ,  $LR_{min}(X)$ ,  $\Delta L_{max}(X)$  and  $\Delta L_{min}(X)$

20    FROM CAMERA

#1        PREDETERMINED VALUE

S636     START APPLYING VIBRATION IN Y AXIS DIRECTION

S637     ISSUE VIBRATION-PROOF CONTROL STARTING  
INSTRUCTION

25    S638     WAIT FOR PREDETERMINED PERIOD OF TIME

S639     ISSUE VIBRATION-PROOF CONTROL ENDING  
INSTRUCTION

S640     END APPLICATION OF VIBRATION IN Y AXIS  
DIRECTION

S641     READ LRmax(Y), LRmin(Y),  $\Delta$ Lmax(Y) AND  $\Delta$ Lmin(Y)  
FROM CAMERA

5   S646     DEFECTIVE MECHANISM OR INSUFFICIENT ADJUSTMENT  
S647     ISSUE VIBRATION-PROOF LENS RESETTNG  
INSTRUCTION

S648     RELEASE CAMERA FROM COMMUNICATION MODE

S649     END PROCESS

10

Figure 10

S700     START COMMUNICATION MODE OF CAMERA

#1     SET INITIAL VALUE OF ANGULAR VELOCITY GAIN  
ADJUSTMENT VALUES

15   #2     CLEAR ANGULAR VELOCITY DETECTING ANGLE  
DISPLACEMENT CORRECTION VALUES

S703     IS VIBRATION-PROOF LENS RESETTNG INSTRUCTION  
ISSUED?

S704     VIBRATION-PROOF LENS RESETTNG PROCESS

20   S705     IS VIBRATION-PROOF LENS CENTERING INSTRUCTION  
ISSUED?

S706     VIBRATION-PROOF LENS CENTERING PROCESS

S707     IS VIBRATION-PROOF ADJUSTMENT STARTING  
INSTRUCTION ISSUED?

25   S708     IS VIBRATION-PROOF CONTROL STARTING INSTRUCTION  
ISSUED?

S709     VIBRATION-PROOF CONTROL STARTING PROCESS

S710 IS VIBRATION-PROOF ADJUSTMENT ENDING  
 INSTRUCTION ISSUED?  
 S711 IS VIBRATION-PROOF CONTROL ENDING INSTRUCTION  
 ISSUED?  
 5 S712 DISABLE VIBRATION-PROOF-CONTROL TIMER INTERRUPT  
 PROCESS AND END VIBRATION-PROOF CONTROL  
 S713 IS DATA READ INSTRUCTION ISSUED?  
 S714 TRANSFER SPECIFIED DATA TO COMMUNICATION TOOL  
 S715 IS DATA WRITE INSTRUCTION ISSUED?  
 10 S716 WRITE DATA TRANSFERRED BY COMMUNICATION TOOL IN  
 PREDETERMINED DATA  
 S717 IS E2PROM WRITE INSTRUCTION ISSUED  
 S718 WRITE DATA TRANSFERRED BY COMMUNICATION TOOL IN  
 E2PROM  
 15 S719 IS COMMUNICATION MODE RELEASE INSTRUCTION  
 ISSUED?  
 S720 END PROCESS

## Figure 11

20 S800 START VIBRATION-PROOF LENS RESETTNG PROCESS  
 S801 START VIBRATION-PROOF LENS RESETTNG (PERMIT  
 VIBRATION-PROOF LENS RESETTNG TIMER INTERRUPT)  
 S802 WAIT FOR PREDETERMINED PERIOD OF TIME  
 S803 IS X AXIS VIBRATION-PROOF LENS RESETTNG ENDED?  
 25 IS  $V_{max}(X)$  EQUAL TO OR LESS THAN PREDETERMINED  
 VALUE?  
 S804 IS Y AXIS VIBRATION-PROOF LENS RESETTNG ENDED?

IS  $V_{max}(Y)$  EQUAL TO OR LESS THAN PREDETERMINED  
VALUE?

S805 RETURN

5 Figure 12

S900 START VIBRATION-PROOF LENS CENTERING PROCESS  
S901 CLEAR X AND Y AXIS VIBRATION-PROOF LENS STOP  
FLG, VIBRATION-PROOF LENS CENTERING TIME-OUT  
ABNORMALITY FLG, X AND Y AXIS VIBRATION-PROOF LENS  
10 MOTION ABNORMALITY FLG AND X AND Y AXIS VIBRATION-PROOF  
LENS POSITION DETECTION ABNORMALITY FLG  
S902 SET VIBRATION-PROOF LENS CENTERING PROCESS  
INTERRUPT TIME-OUT TIME  
S903 START VIBRATION-PROOF LENS CENTERING (PERMIT  
15 THE VIBRATION-PROOF LENS CENTERING TIMER INTERRUPT)  
S904 WAIT FOR PREDETERMINED PERIOD OF TIME  
#1 CLEAR MAXIMUM AND MINIMUM VELOCITIES OF  
VIBRATION-PROOF LENS  
S906 IS VIBRATION-PROOF LENS CENTERING PROCESS  
20 INTERRUPT TIMER TIMED OUT?  
S907 SET VIBRATION-PROOF LENS CENTERING TIME-OUT  
ABNORMALITY FLG  
#2 PREDETERMINED VALUE  
S909 SET X AXIS VIBRATION-PROOF LENS MOTION  
25 ABNORMALITY FLG  
S911 SET Y AXIS VIBRATION-PROOF LENS MOTION  
ABNORMALITY FLG

```

S913    SET X AXIS VIBRATION-PROOF LENS POSITION
DETECTION ABNORMALITY FLG
S915    SET Y AXIS VIBRATION-PROOF LENS POSITION
DETECTION ABNORMALITY FLG
5  S916    IS OPERATION OF VIBRATION-PROOF LENS IN X AXIS
DIRECTION STOPPED?
S917    IS OPERATION OF VIBRATION-PROOF LENS IN Y AXIS
DIRECTION IS STOPPED?
S918    DISABLE VIBRATION-PROOF LENS CENTERING TIMER
10 S919    INTERRUPT PROCESS TO RENDER MOTORS INTO SHORT-BRAKE
STATE TO STOP VIBRATION-PROOF LENS
S919    RETURN

```

## Figure 13

```

15 S1000   START VIBRATION-PROOF CONTROL PROCESS
#1       SET INITIAL VALUE OF VIBRATION-PROOF LENS
TARGET POSITION
#2       CURRENT VIBRATION-PROOF LENS POSITION OF X AXIS
#3       CURRENT VIBRATION-PROOF LENS POSITION OF Y AXIS
20 #4      SET INITIAL VALUE OF MAXIMUM AND MINIMUM VALUES
VIBRATION-PROOF LENS TARGET POSITION
#5       SET INITIAL VALUE OF MAXIMUM AND MINIMUM VALUES
VIBRATION-PROOF LENS POSITION
#6       CLEAR VIBRATION-PROOF LENS POSITION ERROR ΔL
25 S1005   START VIBRATION-PROOF CONTROL (PERMIT THE
VIBRATION-PROOF-CONTROL TIMER INTERRUPT)
S1006   RETURN

```

Figure 14

```

S1100  START VIBRATION-PROOF LENS RESETTING TIMER
      INTERRUPT PROCESS (X AXIS)
5  #1    RENEW VIBRATION-PROOF LENS POSITION
      #2    DETECT VIBRATION-PROOF LENS POSITION
      #3    DETECTED VALUE (X AXIS)
      #4    CALCULATE VIBRATION-PROOF LENS VELOCITY
S1104  DRIVE MOTOR AT PREDETERMINED DRIVE DUTY
10 S1105  END INTERRUPT

```

Figure 15

```

S1200  START VIBRATION-PROOF LENS CENTERING TIMER
      INTERRUPT PROCESS (X AXIS)
15 #1    RENEW VIBRATION-PROOF LENS POSITION
      #2    DETECT VIBRATION-PROOF LENS POSITION
      #3    DETECTED VALUE (X AXIS)
      #4    CALCULATE VIBRATION-PROOF LENS VELOCITY
S1209  SET X AXIS VIBRATION-PROOF LENS STOP FLG
20 S1210  RENDER MOTOR INTO SHORT-BRAKE STATE
      #5    CALCULATE TARGET VELOCITY OF VIBRATION-PROOF
      LENS
S1212  CALCULATE DRIVE DUTY
S1213  DRIVE MOTOR AT SET DRIVE DUTY
25 S1214  END INTERRUPT

```

Figure 16

```

S1300  START VIBRATION-PROOF-CONTROL TIMER INTERRUPT
PROCESS (X AXIS)

#1      RENEW VIBRATION-PROOF LENS POSITION
#2      DETECT VIBRATION-PROOF LENS POSITION
5  #3      DETECTED VALUE (X AXIS)

S1303  DETECTION PROCESS OF MAXIMUM AND MINIMUM VALUES
OF VIBRATION-PROOF LENS POSITION

#4      CALCULATE VIBRATION-PROOF LENS VELOCITY
#5      A/D CONVERT OUTPUT OF YAW ANGULAR VELOCITY
10  DETECTING CIRCUIT

#6      A/D CONVERTED VALUE
#7      CALCULATE GAIN ADJUSTMENT
#8      CALCULATE ANGLE DISPLACEMENT CORRECTION
#9      CALCULATE TARGET VELOCITY OF VIBRATION-PROOF
15  LENS

#10     CALCULATE TARGET POSITION OF VIBRATION-PROOF
LENS

S1310  DETECTION PROCESS OF MAXIMUM AND MINIMUM VALUES
OF VIBRATION-PROOF LENS TARGET POSITION

20  #11     CALCULATE VIBRATION-PROOF LENS POSITION ERROR

S1312  DETECTION PROCESS OF MAXIMUM AND MINIMUM VALUES
OF VIBRATION-PROOF LENS POSITION ERROR

S1313  CALCULATE VIBRATION-PROOF CONTROL DRIVE DUTY
S1314  IS VIBRATION-PROOF ADJUSTMENT PERFORMED?
25  S1315  DRIVE MOTOR AT SET DRIVE DUTY

S1316  END INTERRUPT

```

## Figure 17

S1400 START DETECTION PROCESS OF MAXIMUM AND MINIMUM  
VALUES OF VIBRATION-PROOF LENS POSITION (X AXIS)

S1406 RETURN

5

## Figure 18

S1500 START DETECTION PROCESS OF MAXIMUM AND MINIMUM  
VALUES OF VIBRATION-PROOF LENS TARGET POSITION (X AXIS)

S1503 HOLD SIGNS OF LC(Y)

10 S1506 RETURN

## Figure 19

S1600 START DETECTION PROCESS OF MAXIMUM AND MINIMUM  
VALUES OF VIBRATION-PROOF LENS POSITION ERROR (X AXIS)

15 S1605 RETURN

## Figure 20

S1700 START HALF DEPRESSION PROCESS

#1 READ ANGULAR VELOCITY GAIN ADJUSTMENT VALUE

20 #2 READ DETECTION ANGLE DISPLACEMENT CORRECTION  
VALUE

S1703 IS FULL-DEPRESSION SW TURNED ON?

S1704 IS HALF-DEPRESSION SW TURNED ON?

S1705 END PROCESS

25 S1706 VIBRATION-PROOF LENS CENTERING PROCESS

S1707 VIBRATION-PROOF-CONTROL STARTING PROCESS

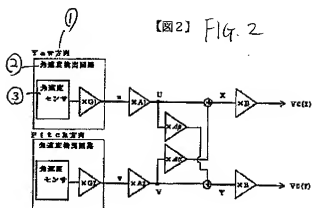
S1708 EXPOSE



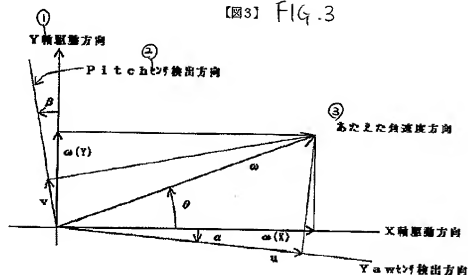
S1709 END VIBRATION-PROOF CONTROL AND RENDER MOTOR  
INTO SHORT BRAKE FOR PREDETERMINED PERIOD OF TIME TO  
STOP VIBRATION-PROOF LENS  
S1710 VIBRATION-PROOF LENS RESETTNG PROCESS  
5 S1711 END PROCESS



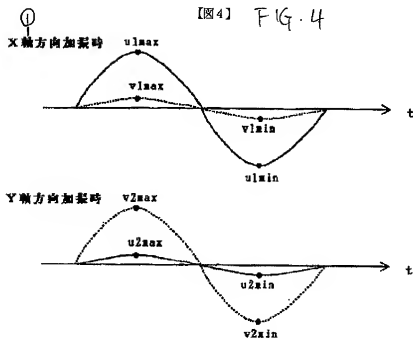
【図2】 Fig. 2



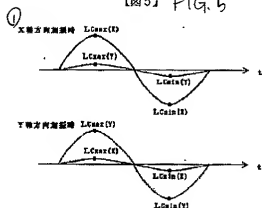
【図3】 Fig. 3



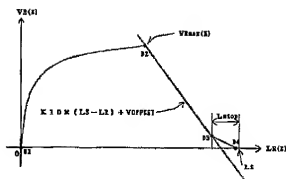
【図4】 Fig. 4



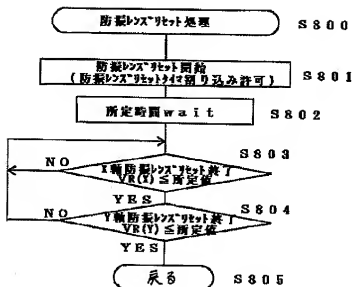
【図5】 Fig. 5



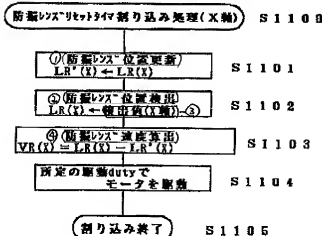
【図6】 Fig. 6



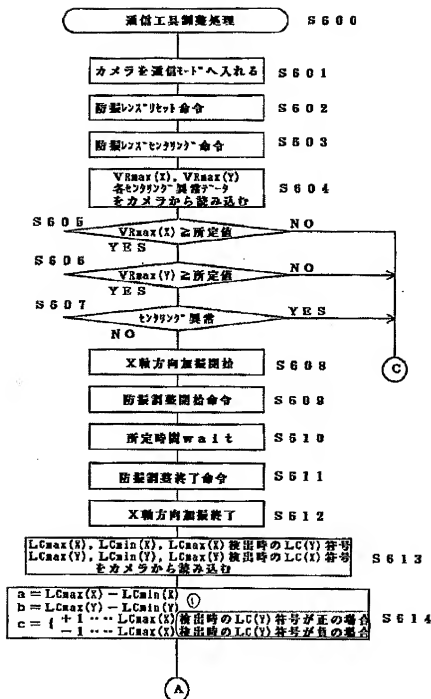
【図11】 Fig. 11



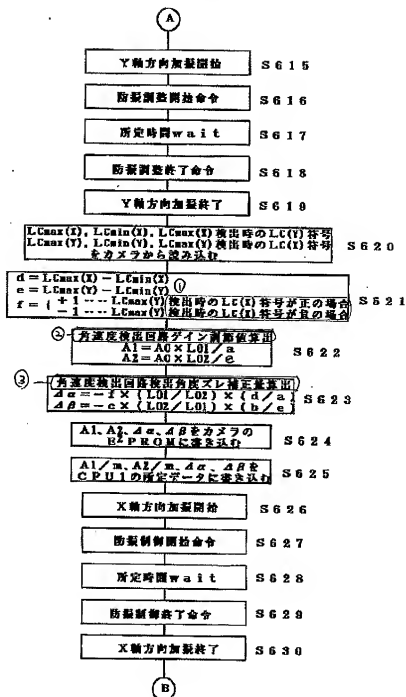
【図14】 Fig. 14



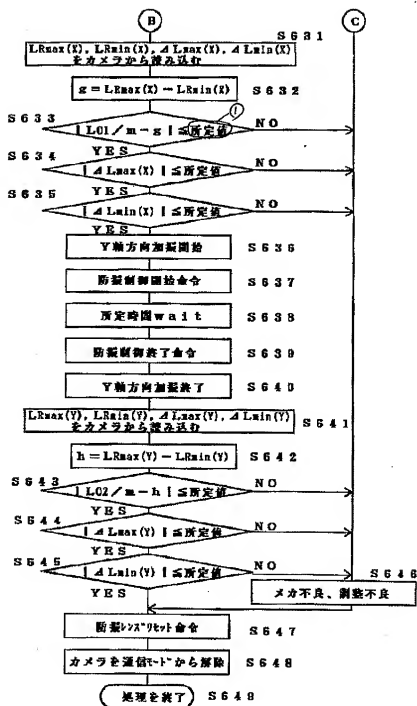
【図7】 FIG. 7



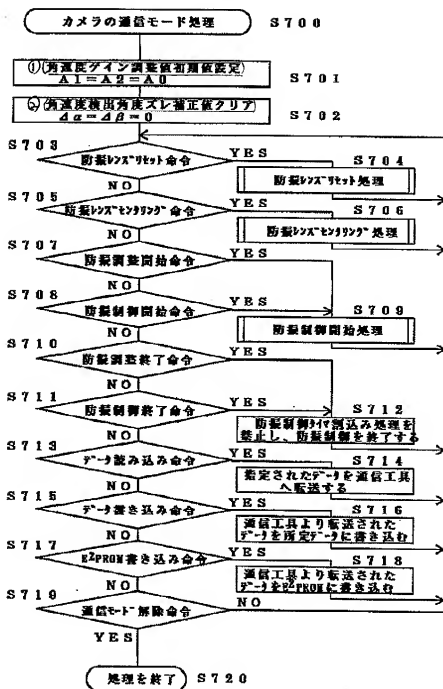
【図8】 FIG. 8



[図9] Fig. 9

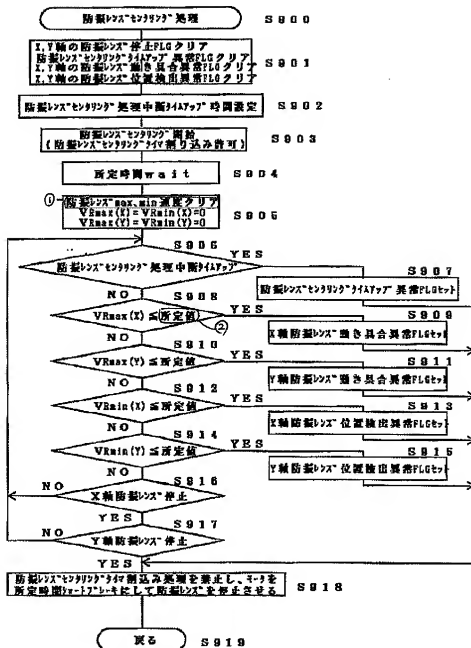


【図10】 FIG.10

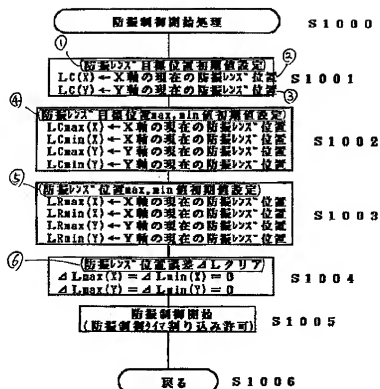




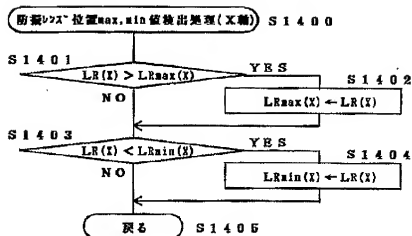
【図12】 FIG. 12



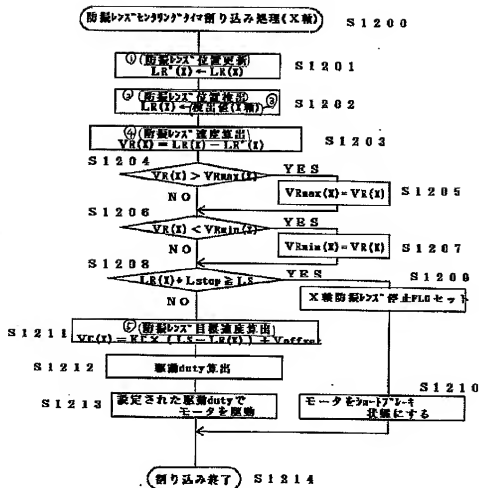
【図13】 FIG. 13



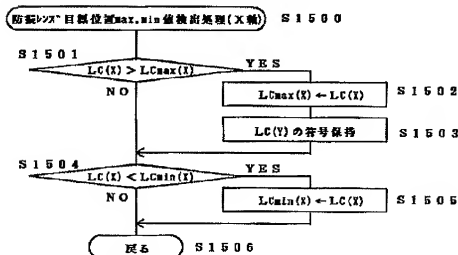
【図17】 FIG. 17



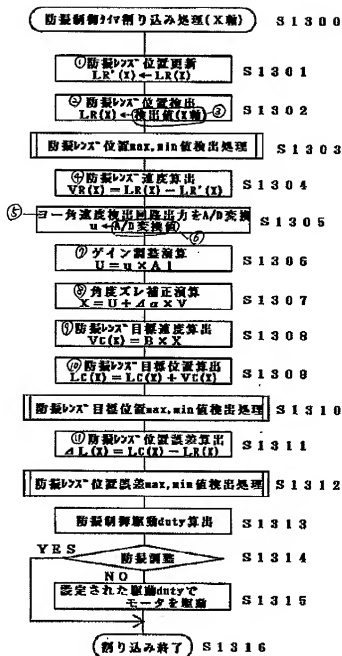
【図15】 FIG. 15



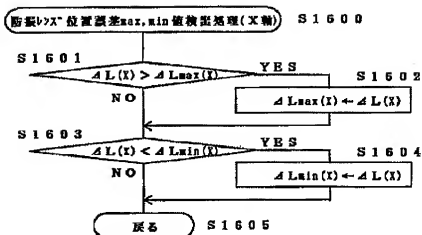
【図18】 FIG. 18



【図16】 FIG. 16



【図19】 FIG. 19



【図20】 FIG. 20

